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Prepared for:

Transportation Development Centre
TRANSPORT CANADA

RESEARCH AND DEVELOPMENT
Canadian Pacific
MONTREAL CANADA

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Prepared for:

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TRANSPORT CANADA

By: RESEARCH AND DEVELOPMENT

Canadian Pacific
MONTREAL, CANADA

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17. Abstract

This final report is a collection of individual reports on research activities carried out under the shared-cost agreement between Canadian Pacific Limited and the Transportation Development Centre during the period March 1987 to April 1988.

This collection includes results of field evaluations of AWC low alloy rail and NKK-AHH rail, and an analysis of the effect of tangent track grinding on reducing truck hunting.

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17. Résumé

Ce rapport final rassemble un certain nombre de rapports de recherche concernant les travaux réalisés aux termes de l'accord de partage des frais de recherche conclu entre le CP et le Centre de développement des transports pour la période allant de mars 1987 à avril 1988.

Ces rapports concernent les évaluations en service des rails AWC en acier allié et NKK-AHH ainsi que l'analyse des effets du reprofilage des voies en alignement visant à réduire le phénomène de la marche en lacet des bogies.

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PREFACE

This report is one of a series of publications intended to present the results of investigations conducted by the Research and Development Department, Canadian Pacific, related to Track/Train Dynamics.

The principal objective of the research activities is to obtain an improved understanding of the dynamic interaction between rail vehicles and between these vehicles and the supporting track structure in order to improve safety and reduce operating and maintenance expenditures.

The elements of this report describe the methodology, results and recommendations of a number of programs that were undertaken in the period March 1, 1987, to April 29, 1988.

It is very gratifying to be able to acknowledge the suggestions and assistance provided by many railway personnel and industry colleagues who assisted in these investigations. Cost-shared financial support provided by the Transportation Development Centre (Transport Canada) permitted our research activities to be more extensive and vigorous than would have been otherwise possible.

A.E. Bethune
General Manager,
Research and Development

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IN-SERVICE EVALUATION OF AN EXPERIMENTAL AWC LOW ALLOY RAIL

K. Griffin
Research and Development
CP Rail
October, 1987

SUMMARY

An experimental head-hardened alloy rail (AWC low alloy rail) produced by Algoma Steel was installed, together with standard NSC Superrail, in an 8.5° curve at MP 60.3 on the Shuswap Subdivision in December, 1985. Metal loss (due to wear, flow and grinding) of this experimental, first generation, AWC low alloy rail was evaluated, in relation to NSC Superrail, using data obtained with the Research and Development Department's rail profilometer. Qualitative field observations were also periodically made to evaluate the relative susceptibilities of these two rail types to surface defect formation.

For both high and low rail positions in the fully developed portion of the test curve, the experimental AWC low alloy rails have consistently experienced more metal loss than comparably located NSC Superrails. Based on profile measurements taken in October, 1987, after 112.1 MGT, the projected service lives of the AWC and NSC rails in this test curve are 5.9 and 7.1 years, respectively. Historically, the service life of Algoma 1.2% Cr rails in this curve has been approximately 4 years.

The experimental AWC low alloy rails exhibited a marked susceptibility to early low rail spalling and required a corrective grinding treatment after less than 50 MGT. This performance is consistent with the shallow, mixed microstructure, surface layer characteristic of these first generation AWC rails. The low rail spalling problem did not significantly develop following the corrective grinding treatment.

The examined first-generation AWC low alloy rail is not an alternative to the NSC Superrail in premium rail applications because of its unacceptable resistance to early surface fatigue damage. To date (112.1 MGT), this AWC rail has also exhibited inferior resistance to metal loss. The relative metal loss performance of these AWC rails is, however, expected to ultimately improve because of their higher through-depth head hardness. Future profile measurements will be taken at this site to determine whether the relative performance of the trial rails does change with increasing metal loss. In-service testing of the next generation of AWC low alloy rails is supported, provided Algoma Steel successfully addresses the AWC rail surface layer problem and a comprehensive metallurgical evaluation indicates that it is at least equivalent to existing premium rails.

SOMMAIRE

La tenue à l'usure de deux rails, le "Superrail" standard de la NSC et le rail expérimental en acier allié à champignon durci par trempe produit par Algoma Steel (rail AWC en acier allié) a été comparée en décembre 1985 dans une voie en courbe de 8,5 degrés au PM 60,3 de la subdivision Shuswap. L'étude comparative des réductions de section (par usure, écoulement plastique et meulage) a été réalisée à l'aide du profilomètre mis au point par le service Recherche et Développement du CP. Des observations périodiques ont également été faites afin de déterminer la susceptibilité relative de ces deux rails aux avaries de surface.

Au milieu de la courbe, le rail Algoma en files extérieure et intérieure a affiché de façon constante une réduction de section supérieure à celle du rail "Superrail" japonais en position comparable. Se fondant sur des mesures profilométriques réalisées en octobre 1987 (trafic écoulé de 112,1 MTB) la durée de vie utile restante des rails Algoma et NSC a été établie pour ce qui concerne le site d'expérimentation, à 5,9 et 7,1 ans, respectivement. Or, les statistiques indiquent que les rails Algoma à 1,2% de Cr implantés sur ce site ont une durée utile d'environ quatre ans seulement.

Le rail expérimental AWC en acier allié a affiché une nette tendance à l'écaillage précoce en file intérieure, nécessitant un meulage correctif avant même que le trafic écoulé n'atteigne 50 MTB. Compte tenu de la faible profondeur et de la microstructure mixte de la couche de surface de ce rail AWC de première génération, les performances constatées ne surprennent point. Après un meulage correctif, l'écaillage du rail en file intérieure n'a pas progressé de façon marquée.

Le rail expérimental AWC de première génération considéré ne saurait donc remplacer avantageusement le "Superrail" de la NSC dans les sites difficiles, à cause d'une résistance insuffisante aux avaries de surface par fatigue précoce. A ce jour (trafic écoulé de 112,1 MTB), il a aussi affiché une réduction de section supérieure à celle du Superrail, mais la situation devrait se redresser avec le temps en raison de la plus grande dureté en profondeur du champignon du rail AWC. D'autres contrôles profilométriques seront effectués sur ce site d'expérimentation afin de déterminer si les performances des deux rails tendent à se rapprocher à mesure que la réduction de section s'accentue. Il a été décidé d'amorcer l'expérimentation de la prochaine génération de rails AWC à la condition que Algoma Steel réussisse à éliminer le problème de la fragilité de la couche de surface et qu'une expertise métallurgique exhaustive les place au moins au rang des rails de première qualité existants.

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1.0 INTRODUCTION

Between 1975-80, the management of Algoma Steel recognized that the use of, and physical demands placed upon, premium rail steels were increasing. It was further realized that the mechanical properties that would soon be required of premium rails would be unattainable by existing alloying practice and that the Algoma 1.2% Cr alloy rail could soon be non-competitive on the world premium rail market.

With the intention of maintaining, and eventually increasing, their share of the premium rail market, Algoma Steel initiated a variety of studies involving different alloy metallurgies as well as heat treatment procedures to standard carbon rails. By 1980, it was concluded that no known alloying route could alone provide sufficient improvement in the mechanical properties of Algoma rails to compare with the best rail product on the market, which at that time was a head-hardened carbon rail from Japan. Conventional off-line heat treatment processes offered the best metallurgical potential for the production of a rail with improved mechanical properties, but off-line facilities offered insufficient productivity to warrant their high capital costs. It was therefore decided

that a novel, on-line, heat-treatment process was necessary to economically produce a competitive premium rail; this novel approach is the Accelerated-Water-Cooling (AWC) process (see Reference 1).

It is generally acknowledged that the best premium rails on today's market are low alloy, head-hardened, rails from Japan (eg. the NSC Superrail). Algoma Steel's stated goals are to upgrade their overall steel and rail processing capabilities, and to produce a commercially viable AWC low alloy rail at least equivalent to the NSC Superrail. Algoma Steel intends this AWC low alloy rail to supersede the use of their 1.2% Cr rail and believes these goals can essentially be reached within 1-2 years.

As part of Algoma Steel's plan to develop the AWC process and an AWC low alloy rail, it was decided to first develop an AWC carbon rail having mechanical properties approaching those of the Superrail and then to use knowledge so gained to develop an AWC low alloy rail of comparable strength and weldability to the Superrail. In 1985, trial AWC carbon rails were installed in CP track along with Algoma 1.2% Cr rail and NSC Superrail in order to obtain in-service comparative metal loss (due to wear, flow and grinding) data under 100-ton unit train service. It was soon recognized that these AWC carbon rails were inadequate for this service; their performance did not

match that of either the 1.2% Cr rail or the NSC Superrail. This stage has since been passed over and Algoma Steel is now concentrating on developing an AWC low alloy rail to compete directly against the various Japanese head-hardened, low alloy, rails.

As part of Algoma Steel's on-going premium rail development program, the first generation of experimental AWC low alloy rails were installed, along with NSC Superrails, at MP 60.3 on the Shuswap Subdivision for in-service comparative metal loss testing in December, 1985.

This report presents the results of in-service comparative metal loss testing of these experimental AWC low alloy rails in relation to the NSC Superrail, along with qualitative field observations of the relative susceptibilities of the trial rails to surface defect formation. Descriptions of the test location and method of data acquisition and analysis are included.

2.0 TEST SITE AND MEASUREMENT POINTS

Details of the physical and metallurgical properties of the NSC Superrail have been given previously (see Reference 2). Briefly, it is a head-hardened Cr/Si/Nb alloy rail. The NSC rail is a minimum 340 BHN rail, but typically exhibits surface

head-hardness values in the 370-380 BHN range. The head-hardness of the NSC Superrail decreases with depth, reaching a base metal hardness of approximately 260 BHN at 1.5 inches below the rail running surface. A comprehensive metallurgical evaluation of the experimental AWC low alloy rail presently in track has not been performed -- this rail (as well as the AWC process) is still in the development stage. The various trial AWC rails encompass a range of Cr-Si chemistries (Cr: 0.5-0.8% and Si: 0.4-0.8%) and head-hardnesses (330-400 BHN). Unlike the NSC rail, the head-hardness of each trial AWC rail does not significantly change with depth. These rails, as was the case for the AWC-340 carbon rails which preceded them (see Reference 3), are characterized by a shallow (0.01-0.10 inch), mixed microstructure, surface layer. The core structure of both the experimental AWC low alloy rail and the NSC Superrail is pearlitic.

The projected specification for the final AWC low alloy rail is that it, like the NSC rail, will be a minimum 340 BHN rail -- but this hardness will be maintained through the depth of the rail head.

In early December, 1985 the Research and Development Department performed initial profile measurements at selected metal loss measurement points on AWC low alloy rails and

standard NSC Superrails while test strings were being welded at the Transcona Rail Yard (see Reference 4). These AWC low alloy rails were installed, along with the NSC Superrails, at MP 60.3 on the Shuswap Subdivision in mid-December, 1985. A plan view of the test site, containing the location of the various metal loss measurement points, is presented in Figure 1. Joint bars were used to connect the AWC low alloy rail to the NSC Superrail. Possible joint effects required that the measurement points be located several feet from the joints; increments of six feet were allowed for in this test.

In April, 1986 spot measurements of track gauge were made throughout the length of the test curve. These measurements were made in response to early spalling of the AWC rails located in the low rail position in the fully developed portion of the curve. The curve typically exhibited 0.25 inch wide gauge with isolated sections having 0.50 inch wide gauge. Subsequent detailed measurements of track curvature, superelevation and gauge were made in October '86, April '87 and October '87 -- as shown schematically in Figures 2, 3 and 4, respectively. These measurements revealed that the gauge of the test curve, particularly the section containing the trial AWC rails, had significantly widened by October '86. Spalling of the low AWC rails had progressed to the point where the entire test curve required a corrective grinding treatment in early-October '86. The gauge of the test site was corrected in mid-October, 1986.

During the April, 1987 inspection it was discovered that the sections of AWC rail containing the high and low rail metal loss measurement points in the fully developed portion of the test curve had been inadvertently removed, discarded and replaced during a late-October '86 restressing operation. It was further determined that the test site had received a preventive grinding treatment in early-May '87 (corrective grinding treatments vary in the amounts of metal removed from the rail head but typically remove 3-4 times the amount of metal removed during preventive grinding). New AWC metal loss measurement points were then selected in the adjacent, unchanged, section of the test curve (see Figure 5) in an attempt to quantify the post-corrective grinding metal loss performance of the AWC rail.

As of the final profile measurements in October '87, the test curve had experienced 112.1 MGT. Information on the traffic passing over the test site was supplied by the Chief Statistician, CP Rail.

3.0 DATA COLLECTION AND ANALYSIS

All profile data was collected with the rail profilometer (see Reference 5) developed by the Research and Development Department, CP Rail, and processed on the microcomputer in the department.

New profile measurements were first taken at the selected metal loss measurement points in early-December, 1985 -- during the welding of the test rail strings at the Transcona Rail Yard. Research and Development personnel were present on December 11, 1985 when these rail strings were installed at MP 60.3, Shuswap Subdivision.

Subsequent profile measurements were taken at these selected points in April '86 and before/after grinding in mid-October '86. Removal of the rail sections containing the original AWC measurement points in the fully developed portion of the test curve in late-October '86 necessitated the selection of "new" AWC measurement points in April '87 (see Figure 5). Profile measurements were performed at the original NSC points, and at the new (i.e. curve portion) and original (i.e. tangent section) AWC points in April '87 and again in October '87. Qualitative field observations of the surface defects exhibited by the two rail types were made during each series of profile measurements.

For each profile comparison, three indices of relative metal loss are reported. These are: vertical head loss, loss at the gauge face and head area reduction. The vertical and gauge face losses are calculated in accordance with standard practice (see Reference 6), as shown in Figure 6. The area reduction calculations consider as lost the material which has

been removed from the rail head and material that has flowed outside the original profile. The resolution limit of the profilometer for vertical and gauge face loss is 0.004 inches, and approximately 0.016 square inches for total head area loss. For profile matching purposes, a difference of 0.008 inches has been specified as the minimum difference required to constitute significant vertical and/or gauge face loss; 0.032 square inches has been specified for total head area loss comparisons.

4.0 RESULTS AND CONCLUSIONS

4.1 Metal Loss Analysis

Two different periods will be considered in evaluating the relative performance of the trial rails:

PERIOD I: installation → corrective grinding in October, 1986

PERIOD II: installation → final measurements in October, 1987

This method of examination accounts for the significant change in the AWC portion of the test curve which occurred in October, 1986.

The metal loss versus tonnage variations for all the measurement points in the AWC low alloy rail test program are listed in Table 1.

PERIOD I

As of October, 1986 neither the NSC Superrails nor the AWC low alloy rails had experienced sufficient metal loss to allow for meaningful estimates of their relative "wear" lives.

Profile measurements taken before grinding in October, 1986 (46.4 MGT) revealed:

a) Neither AWC low alloy rails nor NSC Superrails located in the tangent track section had experienced significant metal loss.

b) AWC low alloy rails located in the low rail position in the fully developed portion of the 8.5° curve had experienced, on average, 38% and 26% more vertical and total head area metal loss, respectively, than similarly positioned NSC Superrails.

c) NSC Superrails located in the high rail position in the fully developed portion of the 8.5° curve had experienced, on average, 0.011 inches of vertical head loss, negligible gauge face loss and 0.073 square inches of total head area loss.

d) Corresponding high AWC low alloy rails had experienced, on average, 0.015 inches of vertical head loss, 0.040 inches of gauge face loss and 0.073 square inches of total head area loss.

PERIOD II

Conclusions on the relative metal loss performance of the trial rails over the course of the entire test program are based on the assumption that the "new" AWC metal loss measurement points selected in April '87 (see Figure 5) exhibited the same initial profiles as the original AWC metal loss measurement points. This assumption is potentially incorrect due to rolling tolerances. Further, the $^{+}$40 foot distance between the post-April '87 AWC and NSC rail metal loss measurement points may result in their experiencing different wheel/rail interaction and dynamic loading effects.

One of the claimed benefits of the AW approach is the ability to achieve approximately uniform, through-depth, rail head hardnesses (as compared to the negative hardness gradients achieved with conventional off-line heat treatment procedures). A rail with such a uniform through-depth hardness pattern could ultimately exhibit superior metal loss and fatigue properties, relative to an initially harder rail with a negative hardness gradient, after sufficient metal loss. Analysis of NSC and AWC low alloy rail data (see References 7 and 8) suggests that this depth of metal loss is approximately 0.040 inches. This portion of the analysis is an attempt to assess the post-grinding (October, 1986) performance of the AWC rail and to investigate whether the relative performance of the trial rails has changed with increasing metal loss.

Profile measurements taken in October, 1987 (112.1 MGT) revealed:

a) Neither AWC low alloy rails nor NSC Superrails located in the tangent track section had experienced significant metal loss.

b) AWC low alloy rails located in the low rail position in the fully developed portion of the 8.5° curve had experienced, on average, 38% and 23% more vertical and total head area loss, respectively, than similarly positioned NSC Superrails.

c) NSC Superrails located in the high rail position in the fully developed portion of the 8.5° curve had experienced, on average, 0.062 inches of vertical head loss, 0.058 inches of gauge face loss and 0.257 square inches of total head area loss.

d) Corresponding high AWC low alloy rails had experienced, on average, 0.107 inches of vertical head loss, 0.060 inches of gauge face loss and 0.306 square inches of total head area loss.

Interestingly, if only the post-corrective grinding (October, 1986) profile measurements are considered, the relative performance of low AWC rails has significantly improved (on average, 17% and 13% more vertical and total head area metal loss, respectively, than similarly positioned low NSC Superrails). Over the same period, however, the relative performance of high AWC rails has slightly worsened ($^{+}$25% more total head area loss).

As of October, 1987 the trial rails in the fully developed portion of the test curve had experienced 112.1 MGT. Experience with other premium rails [2,9,10] suggests that

stable wear (not necessarily metal loss) rates should have been achieved after, at most, 100 MGT. The trial AWC and NSC rails do not, however, exhibit stable metal loss versus tonnage patterns (see Table 2). This is likely due to the failure to obtain before/after grinding profiles in May '87, which accounts for the increased rates of metal loss between April and October, 1987. It is assumed that sufficient tonnage has passed over the test curve for a comparison of the NSC and AWC rails on the basis of cumulative metal loss. Relative service life projections were made for the trial rails in the fully developed portion of the test curve by extrapolating their averaged rates of metal loss (see Table 1), up to the point where the high rail becomes condemnable. This approach does not account for the fundamentally different head-hardness gradients exhibited by the trial rails. The accuracy of this predictive approach increases with increasing metal loss. For purposes of analysis, a 20% loss of total head area was selected as the condemning criteria*. Under the given test conditions, the average projected service life of the high NSC rails is approximately 425 MGT (7.1 years)

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* This approach is overly simplistic in that an infinite number of worn profiles can exhibit a 20% loss of head area, and only some of these profiles would be condemnable. In reality, various combinations of vertical and gauge face loss can determine the service life of a rail. These combinations are determined by consideration of allowable lateral clearances, possible impacting between worn wheels and rail joint bars, and beam strength. A maximum head area loss approach, while simplistic, is valid on a comparative basis between the trial rails.

whereas the average projected service life of the high AWC low alloy rails is approximately 355 MGT (5.9 years). Based on conversations with field personnel, the average "wear" life of Algoma 1.2% Cr rails in the test curve has historically been approximately 4 years.

4.2 Surface Defects

As of October, 1987 (112.1 MGT) trial rails located in tangent and spiral sections of the test site did not exhibit significant surface damage.

Spalling of the running surface of AWC low alloy rails located in the low rail position in the fully developed portion of the test curve was first observed in May, 1986 (20.2 MGT). This spalling (see Figure 7) was particularly noticeable near weld joints and at locations where the tie plates for corresponding high rail locations were digging into the ties. This performance was not unexpected in light of the shallow, mixed microstructure, surface layer which characterizes this first generation of AWC low alloy rail. Similarly located low NSC Superrails did not exhibit surface defects. As noted previously (see Reference 11), this surface layer is considered significantly responsible for the poor performance of these AWC low alloy rails in low rail service. This surface layer feature alone prevents these experimental AWC

low alloy rails from being considered as a viable premium rail product and must be eliminated before a future AWC rail can be seriously considered as a potential replacement for the standard NSC Superrail.

No surface defects were noted on either trial rail in the high rail position during the May, 1986 inspection.

By October, 1986 (46.4 MGT) the spalling exhibited by low AWC rails had significantly worsened (see Figures 8 and 9) and the entire test site received a corrective grinding treatment. The grinding train was unable to completely remove all of these surface defects (see Figure 10). Corresponding low NSC Superrails exhibited only intermittent mild spalling before grinding (see Figure 11). These surface defects were removed by grinding.

In addition to a weak surface layer, the accelerated spalling of low AWC rails was partly due to wide gauge. By October, 1986 the sections containing AWC low alloy rails were consistently over gauge by 0.50 inches (see Figure 2); some areas of very severe spalling were over gauge by 0.75 inches. Experience suggests that track that is 0.50 inches, or more, over gauge will experience accelerated spalling. The NSC Superrail portion of the test curve did not exhibit the same degree of wide gauge. The test site gauge was corrected in mid-October, 1986.

Prior to grinding in October, 1986 high NSC Superrails exhibited intermittent, shallow, gauge corner shells (see Figure 12) throughout the length of the test curve as well as an isolated case of more significant gauge corner shell (see Figure 13). Corresponding high AWC rails exhibited no surface defects. Neither the small, shallow, gauge corner shells nor the isolated larger case were removed by grinding (see Figure 14).

The mild gauge corner shell exhibited by high NSC Superrails was also observed in a previous rail evaluation program (see Reference 2) and is believed to be a result of the NSC rail geometry (i.e. flat running surface, sharper gauge corner) and high yield strength. Research has no explanation for the isolated, significant, gauge corner shell shown in Figure 13.

Field observations made during the April '87 and October '87 inspection programs confirmed that the surface defects that were not completely removed in October '86 had not significantly developed (see Figures 15 and 16) -- nor had any significant new defects appeared. The test site had received a preventive grinding treatment in May, 1987. These observations confirm that the susceptibility to early spalling of the AWC rail is a surface layer problem; Algoma Steel is presently addressing this problem.

5.0 RECOMMENDATIONS

- Detailed monitoring of the first generation AWC low alloy rails should be discontinued because of the significant changes that have been made to this test site. Rail profiles at this test site should still be periodically measured, in conjunction with future rail evaluation programs, to determine whether the relative performance of the trial rails changes with increasing metal loss.

- The examined experimental AWC low alloy rail should not be considered as a potential replacement for the standard NSC Superrail.

- The next generation of AWC low alloy rail should be tested in-service provided the surface layer problem has been corrected and a comprehensive metallurgical evaluation indicates that it is at least equivalent to existing premium rails. Any such future rail evaluation program should include multiple test sites; the Research Department should receive notification prior to any scheduled maintenance to these sites.

REFERENCES

1. "Algoma Head-Hardened Carbon Steel Rail (AWC-340 Rail)", internal memorandum, Research and Development Department, CP Rail, December 1984.

2. "Field Evaluation of the Wear Performance of Japanese Head-Hardened Alloy Rail (NSC Superrail)", K. Griffin, L. Feiter and H. Schrekinger, Research and Development Department, CP Rail, Report No. T-881-85, June 1985.

3. "In-Service Evaluation of AWC-340 Carbon Rail", K. Griffin, Research and Development Department, CP Rail, Report No. T-923-86, May 1986.

4. "AWC-340 Rail Welding Trials -- Weld Analysis", K. Griffin, Research and Development Department, CP Rail, Report No. T-899-85, December 1985.

5. "A Wheel/Rail Profilometer System", G. Izbinsky, H. Schrekinger and H. Soares, Research and Development Department, CP Rail, Report No. T-805-84, February 1984.

6. "Standard Practice Circulars: Track", CP Rail.

7. "Manufacture and Properties of DHH (Deep Head Hardened) Rails", H. Yoshitake et. al., taken from the Transportation Research Board Symposium on Rail Replacement Strategies and Maintenance Management, University of Illinois, June 1987.

8. "AWC Rail Research Project Specifications", Research Department, Algoma Steel, 1986.

9. "Field Evaluation of the Wear Performance of Russian P-65 Rail", K. Griffin, Research and Development Department, CP Rail, Report No. S799-83, December 1983.

10. "Rail Assessment", P. Mutton, C. Epp and S. Marich, taken from the Proceedings of the 2nd International Heavy Haul Railways Conference, Colorado Springs, Colorado, U.S.A., 1982.

11. "In-Service Evaluation of AWC Low Alloy Rail -- Preliminary Report", K. Griffin, Research and Development Department, CP Rail, Report No. T-922-86, May 1986.

Table 1

Metal Loss Data for AWC Low Alloy Rail Test Site, MP 60.3, Shuswap Subdivision

Measurement Point and Description*	Indice of Metal Loss	Cumulative Tonnage (MGT) 0(Ref.)	20.2	46.4**	46.4***	84.2	112.1
1- Tangent NSC	Vertical (in.)	0	0	.016	.012	.012	.028
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	.002	.024	.033	.034	.098
2- Tangent NSC	Vertical (in.)	0	0	.008	.008	.016	.024
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	0	.016	.021	.054	.084
3- Tangent NSC	Vertical (in.)	0	0	.008	0	.012	.024
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	0	.018	.012	.034	.083
4- LJ (8.5° curve)	Vertical (in.)	0	.024	.039	.043	.075	.106
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	.027	.063	.091	.147	.238
5- LJ (8.5° curve)	Vertical (in.)	0	.020	.039	.043	.075	.106
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	.028	.069	.103	.163	.256
6- LJ (8.5° curve)	Vertical (in.)	0	.028	.043	.043	.083	.114
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	.036	.073	.097	.181	.264
7- HJ (8.5° curve)	Vertical (in.)	0	0	.008	.008	.031	.055
	Gauge Face (in.)	0	0	0	0	.024	.055
	Total Area (sq.in.)	0	.020	.062	.084	.157	.242
8- HJ (8.5° curve)	Vertical (in.)	0	.012	.016	.028	.039	.075
	Gauge Face (in.)	0	0	0	.016	.039	.063
	Total Area (sq.in.)	0	.033	.084	.136	.181	.282
9- HJ (8.5° curve)	Vertical (in.)	0	0	.008	0	.031	.055
	Gauge Face (in.)	0	0	0	0	.024	.055
	Total Area (sq.in.)	0	.019	.073	.084	.154	.246
10- Tangent NSC	Vertical (in.)	0	0	0	0	.016	.035
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	.001	.017	.022	.040	.115
11- Tangent NSC	Vertical (in.)	0	0	0	.012	.020	.031
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	0	.007	.026	.047	.095

Table 1 (Cont'd.)

Metal Loss Data for AWC Low Alloy Rail Test Site, MP 60.3, Shuswap Subdivison

Measurement Point and Description*	Indice of Metal Loss	Cumulative Tonnage (MGT) 0(Ref.)	20.2	46.4**	46.4***	84.2	112.1
12- Tangent NSC	Vertical (in.)	0	0	0	0	.016	.028
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	.001	.012	.019	.043	.094
13- Tangent AWCLA	Vertical (in.)	0	0	.012	.008	.020	.039
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	.003	.031	.017	.046	.104
14- Tangent AWCLA	Vertical (in.)	0	0	.012	.008	.020	.035
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	.001	.019	.028	.054	.087
15- Tangent AWCLA	Vertical (in.)	0	0	.008	0	.012	.028
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	0	.002	.013	.024	.067
16- HAWCLA (8.5° curve)	Vertical (in.)	0	0	.016	.031	.079	.114
	Gauge Face (in.)	0	0	.043	.047	.031	.063
	Total Area (sq.in.)	0	.007	.071	.118	.212	.314
17- HAWCLA (8.5° curve)	Vertical (in.)	0	0	.012	.020	.079	.110
	Gauge Face (in.)	0	0	.039	.028	.039	.063
	Total Area (sq.in.)	0	.006	.073	.092	.217	.322
18- HAWCLA (8.5° curve)	Vertical (in.)	0	0	.016	.028	.067	.098
	Gauge Face (in.)	0	.016	.039	.039	.031	.055
	Total Area (sq.in.)	0	.009	.074	.115	.193	.282
19- Tangent AWCLA	Vertical (in.)	0	0	0	0	.016	.039
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	0	.026	.017	.044	.104
20- Tangent AWCLA	Vertical (in.)	0	0	0	.008	.020	.031
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	0	.005	.009	.029	.074
21- Tangent AWCLA	Vertical (in.)	0	0	0	0	.012	.035
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	0	.007	.007	.022	.082
22- LAWCLA (8.5° curve)	Vertical (in.)	0	.028	.063	.083	.122	.161
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	.034	.092	.149	.224	.332

Table 1 (Cont'd.)

Metal Loss Data for AWC Low Alloy Rail Test Site,
MP 60.3, Shuswap Subdivision

Measurement Point and Description*	Indice of Metal Loss	Cumulative Tonnage (MGT) 0(Ref.)	20.2	46.4**	46.4***	84.2	112.1
23- LAWCLA (8.5° curve)	Vertical (in.)	0	.028	.051	.071	.110	.154
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	.036	.085	.135	.212	.318
24- LAWCLA (8.5° curve)	Vertical (in.)	0	.024	.051	.063	.102	.134
	Gauge Face (in.)	0	0	0	0	0	0
	Total Area (sq.in.)	0	.032	.082	.120	.191	.281

---

* The following abbreviations designate the rail position and type particular to each measurement point:

HJ/LJ - Japanese Superrail on high/low rail of curve
HAWCLA/LAWCLA - AWC Low Alloy Rail on high/low rail of curve

** Profile measurements taken before corrective grinding treatment in October, 1986

*** Profile measurements taken after corrective grinding treatment in October, 1986

Table 2

Relative Rail Performance at Different Traffic Levels

Rail Type	Position	Rate of Metal Loss (sq.in./MGT) 0-20.2	20.2-46.4*	46.4*-84.2	84.2-112.1**
NSC Superrail	high	.0012	.0019	.0017	.0033
NSC Superrail	low	.0015	.0015	.0018	.0032
AWC Low Alloy	high	.0003	.0024	.0026	.0035
AWC Low Alloy	low	.0017	.0020	.0020	.0036

* - Does not include metal removed during October '86 corrective grinding treatment.

** - Includes metal removed during May '87 preventive grinding treatment.

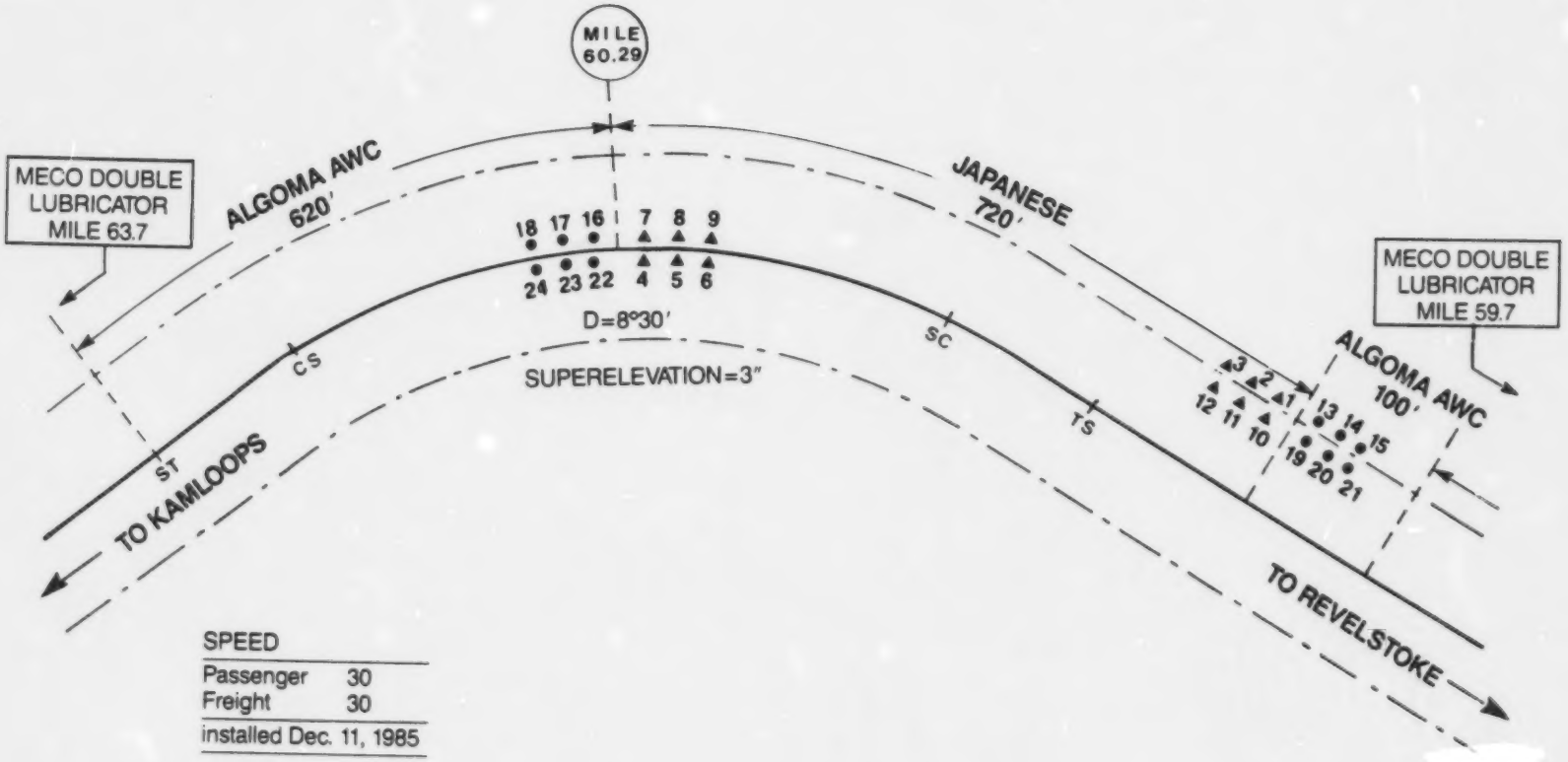

Figure 1: TRACK LAYOUT WITH CURVATURES AND LOCATION OF CHANGE-OVER/MEASUREMENT POINTS FOR AWC LOW ALLOY RAIL TEST SITE AT MP 60.3, SHUSWAP SUBDIVISION.

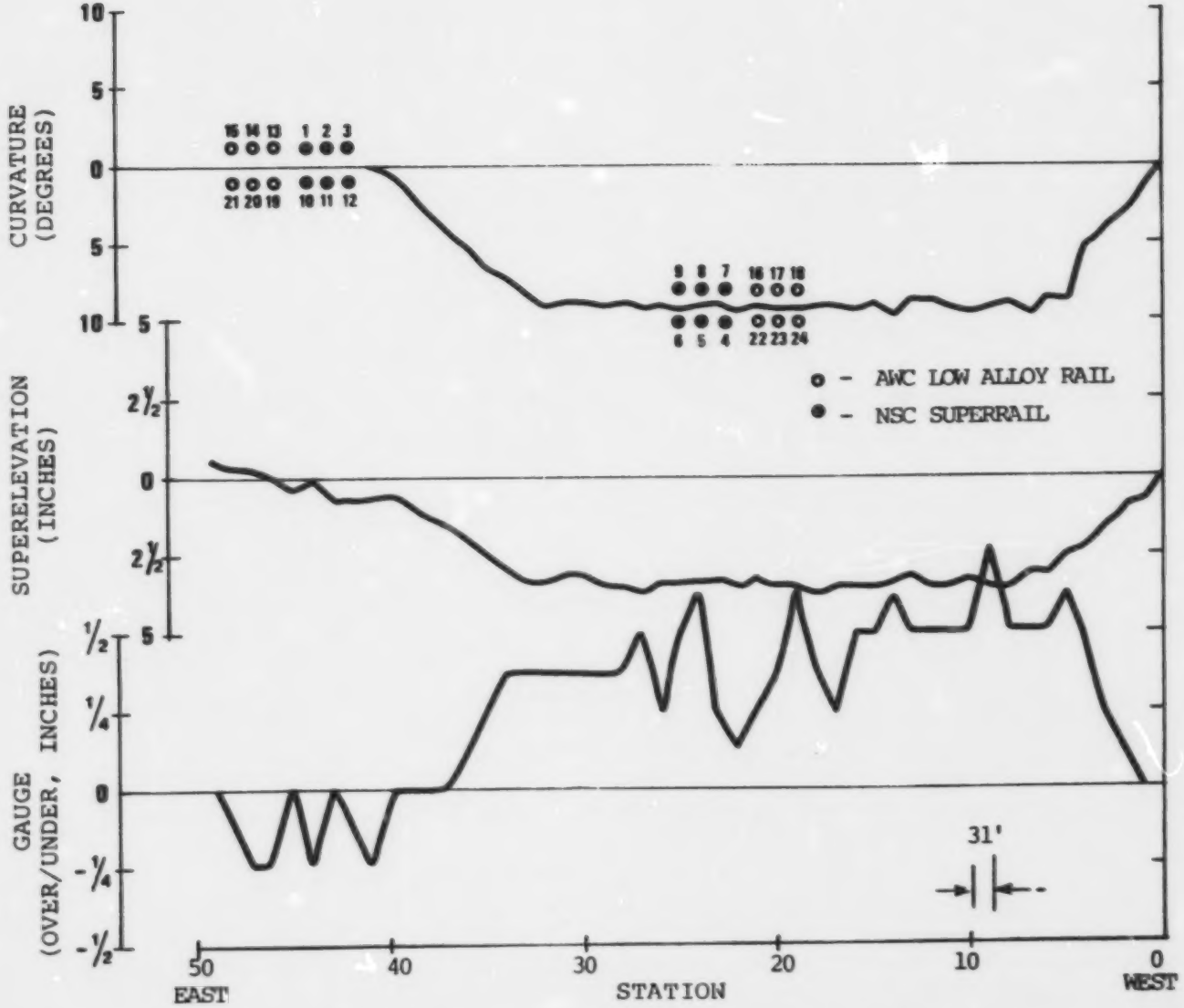

Figure 2: Curvature, Superelevation, Track Gauge and Location of Measurement Points for AWC Low Alloy Rail Test Site, MP 60.3, Shuswap Subdivision (October, 1986)

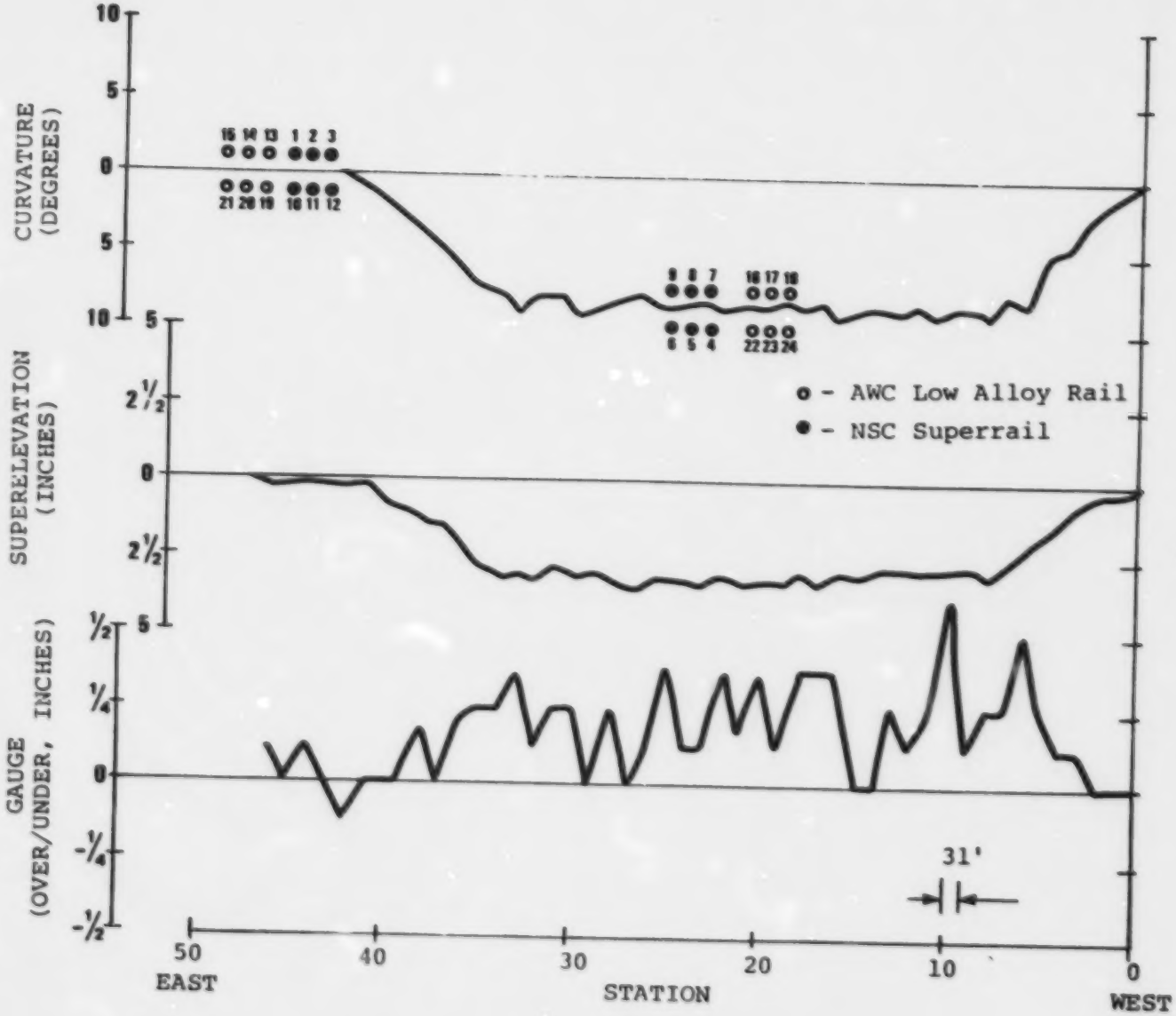

Figure 3: Curvature, Superelevation, Track Gauge and Location of Measurement Points for AWC Low Alloy Rail Test Site, MP 60.3, Shuswap Subdivision (April, 1987)

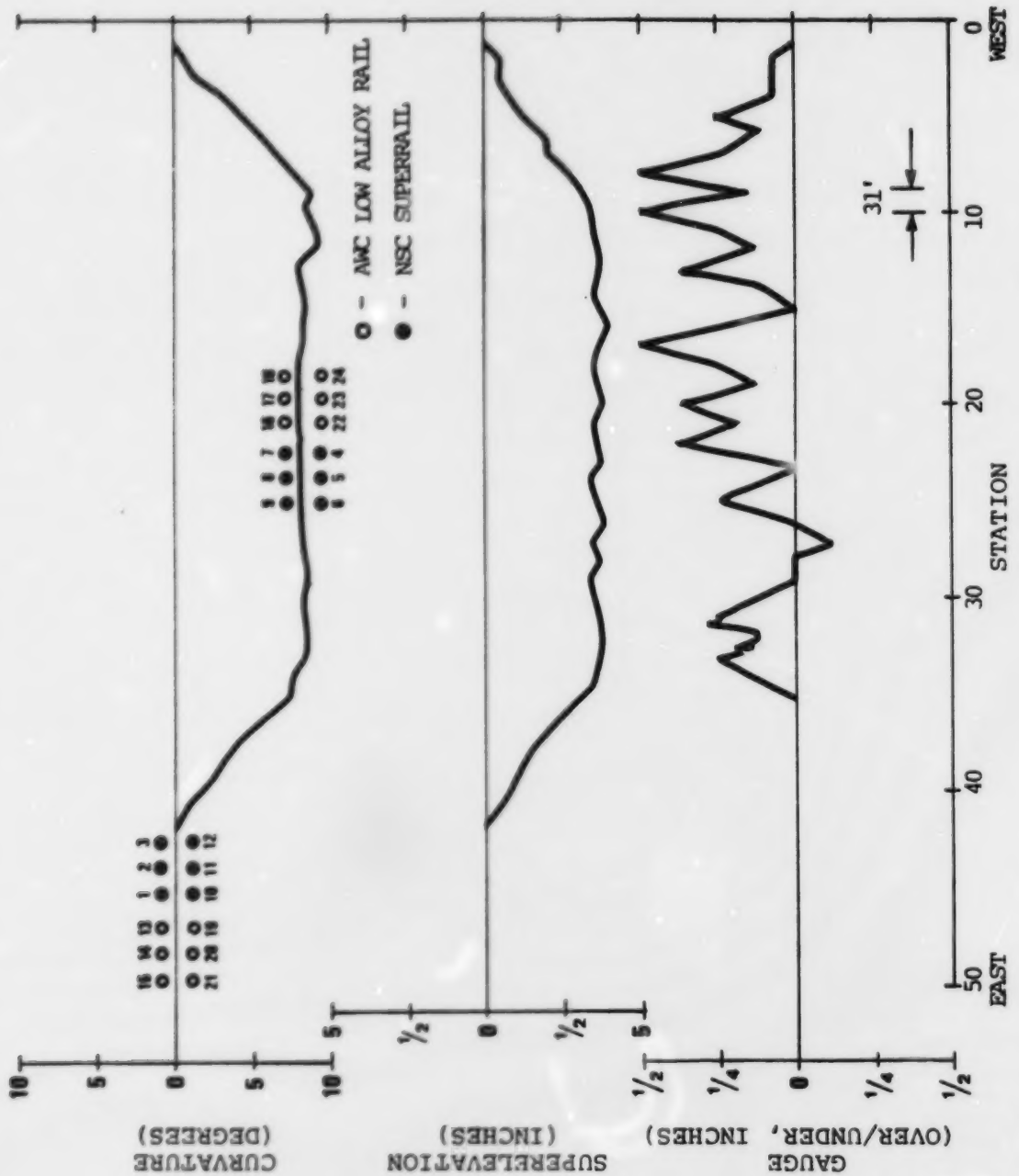

Figure 4: Curvature, Superelevation, Track Gauge and Location of Measurement Points for AMC Low Alloy Rail Test Site, MP 60.3, Shuswap Subdivision (October, 1987)

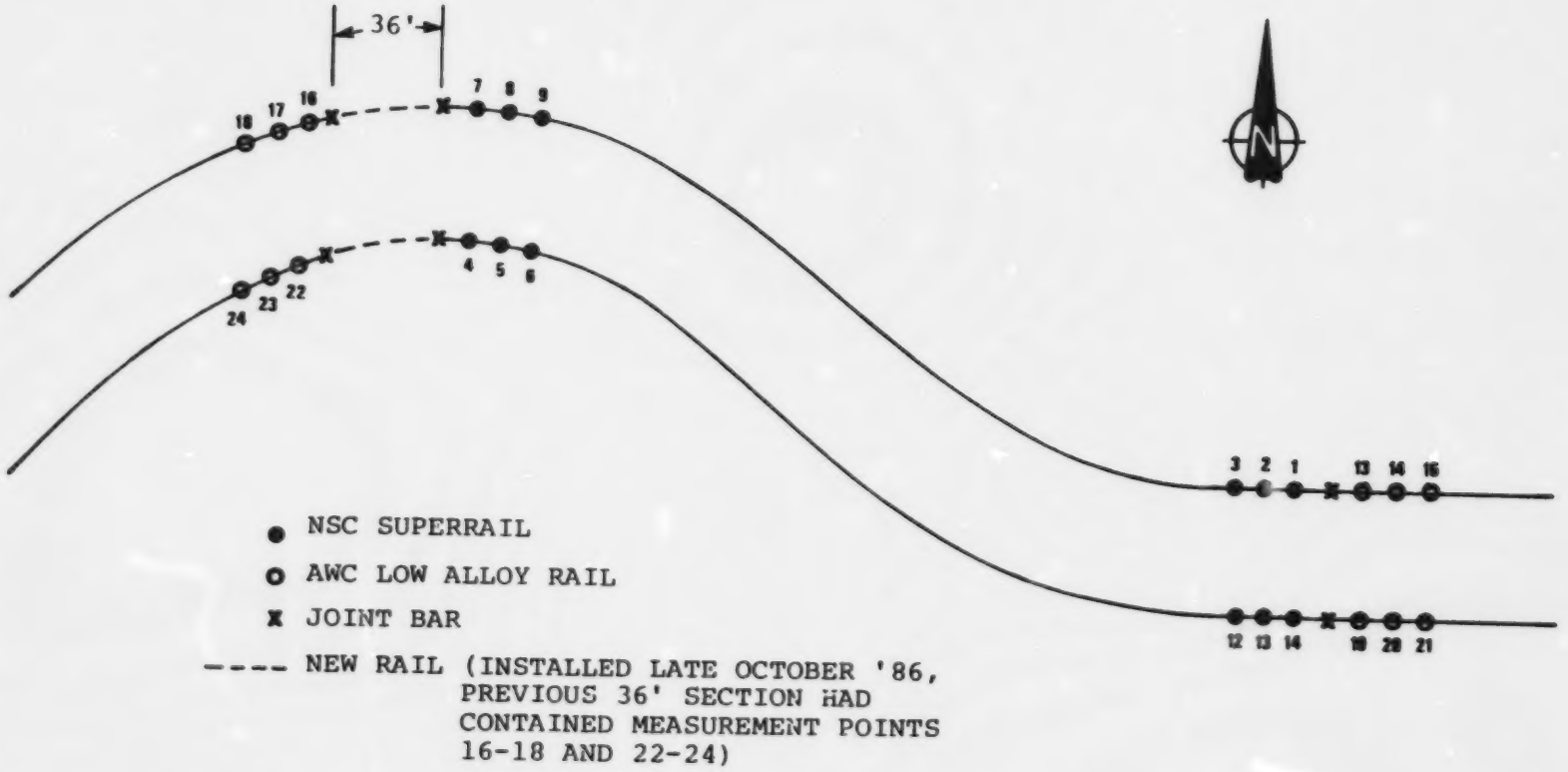

Figure 5: Location of "New" AWC Low Alloy Rail Measurement Points

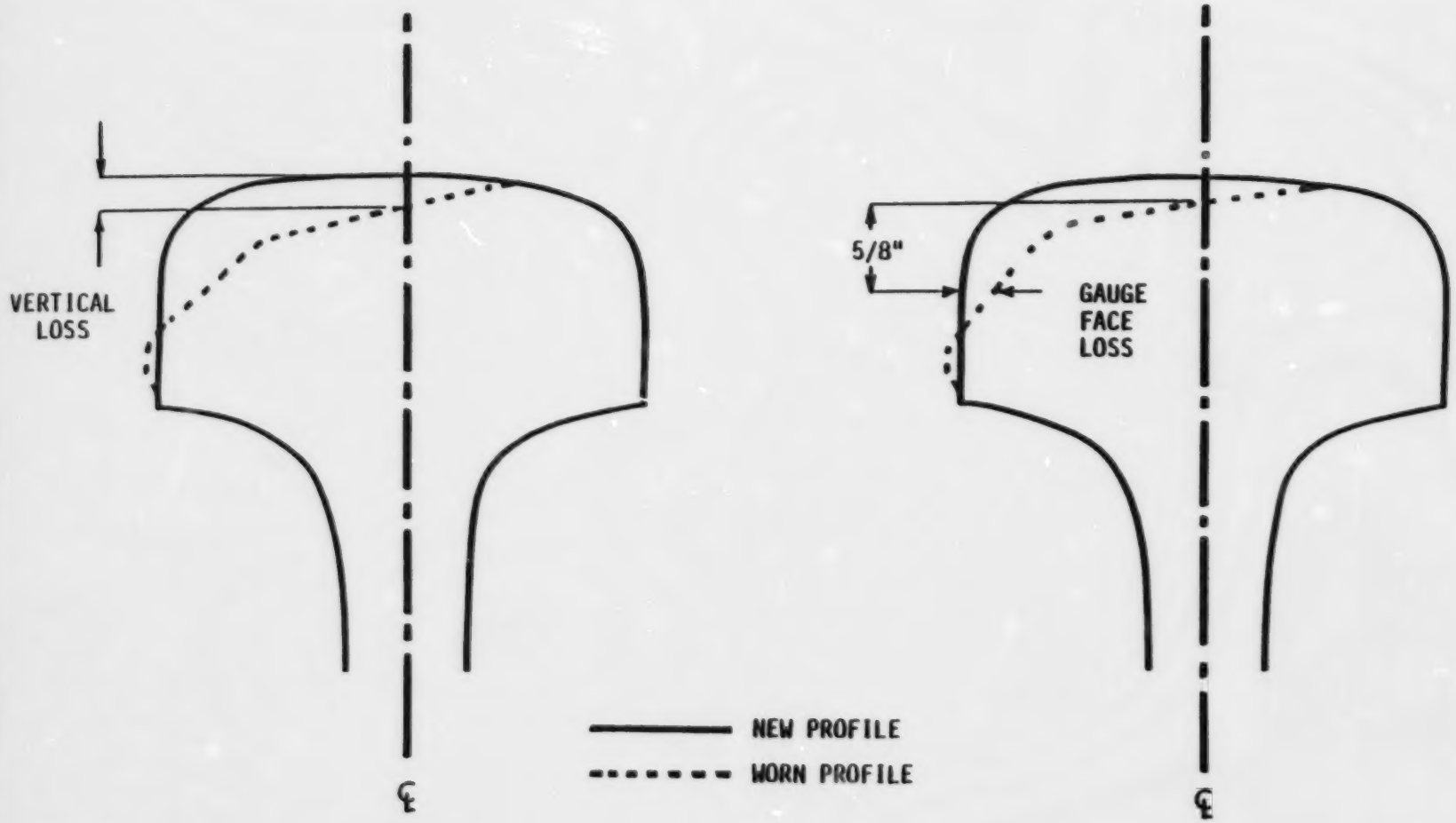

Figure 6: Definition of Vertical and Gauge Face Losses

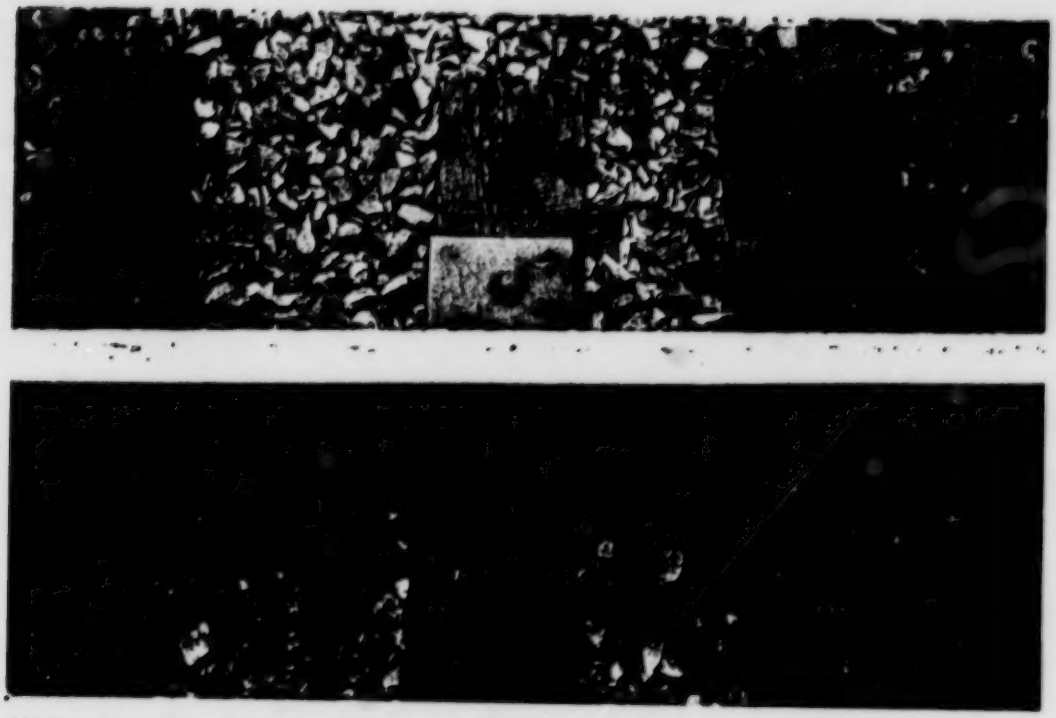

Figure 7: Spalling Exhibited by AWC Low Alloy Rail in Low Rail Position in Fully Developed Portion of 8.5° Curve (May, 1986)

Figure 8: Typical Spalling and Flow Exhibited by AWC Low Alloy Rail Located in the Low Rail Position in the 8.5° Curve (Before Grinding, October, 1986)

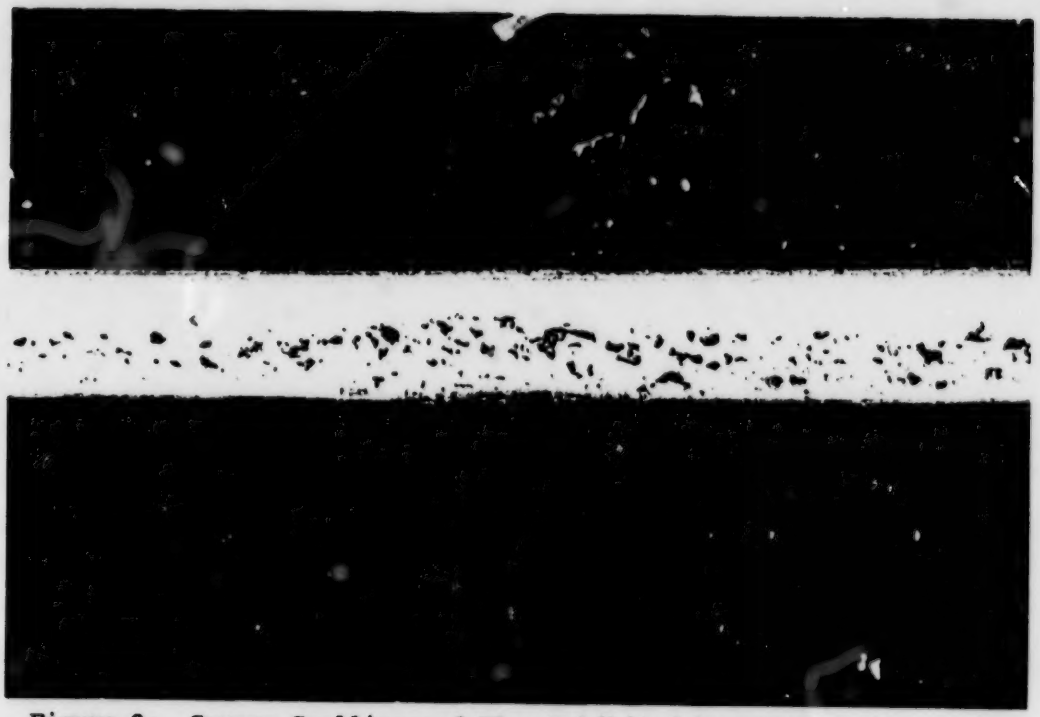

Figure 9: Severe Spalling and Flow Exhibited by AWC Low Alloy Rail Located in the Low Rail Position in the 8.5° Curve (Before Grinding, October, 1986)

Figure 10: Typical Running Surface of AWC Low Alloy Rail, Following Grinding in October 1986, Located in the Low Rail Position of the 8.5° Test Curve

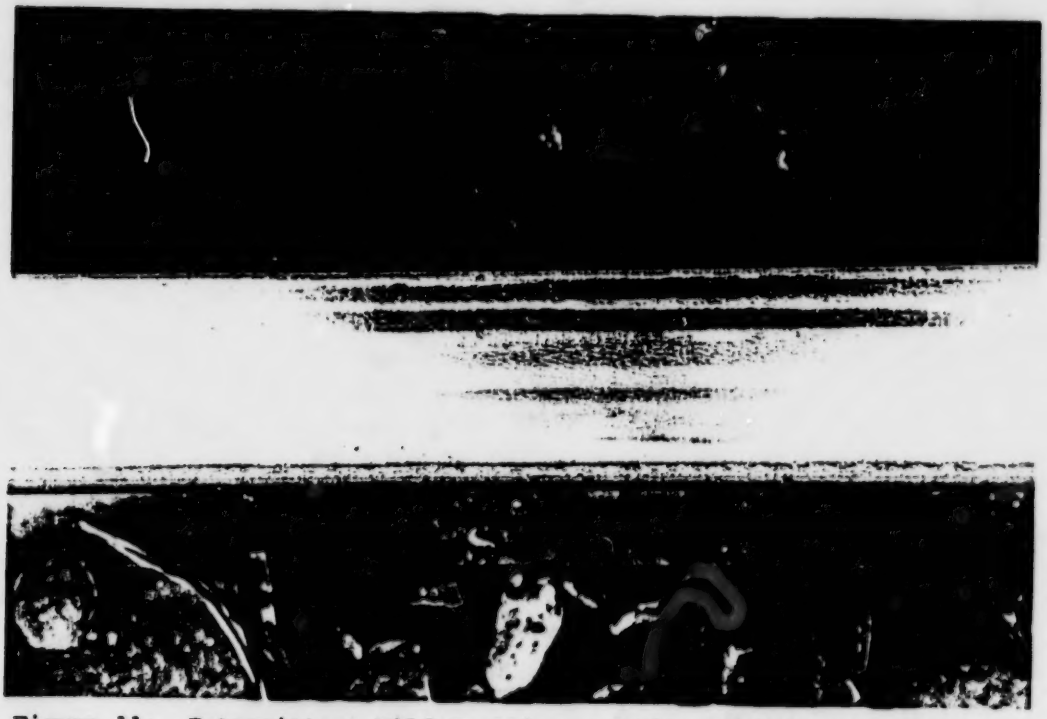

Figure 11: Intermittent Mild Spalling and Flow Exhibited by NSC Superrail in the Low Rail Position of the 8.5° Test Curve (Before Grinding, October, 1986)

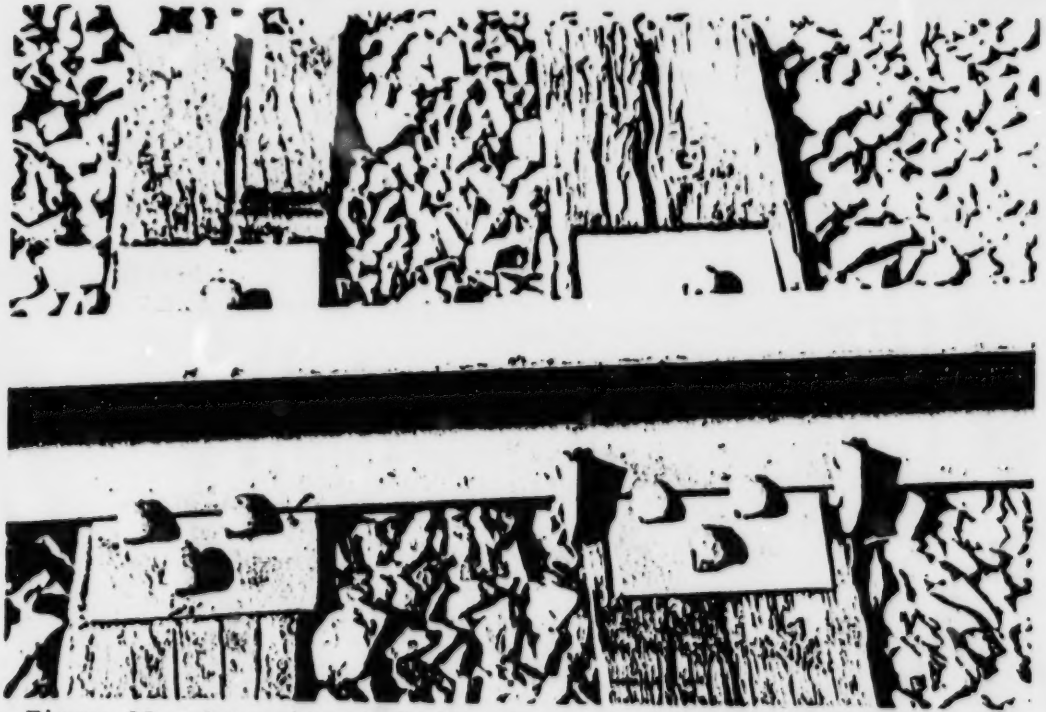

Figure 12: Intermittent Shallow Gauge Corner Shell Exhibited by NSC Superrails Located in the High Rail Position of the 8.5° Test Curve (Before Grinding, October, 1986)

Figure 13: Severe Gauge Corner Shell Exhibited by NSC Superrail Located in the High Rail Position of the 8.5° Test Curve (Before Grinding, October 1986)

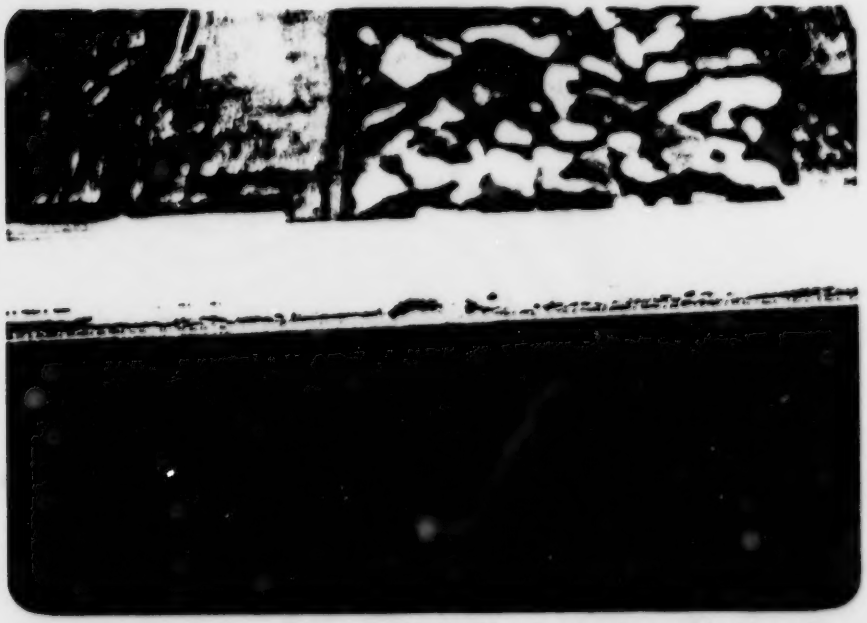

Figure 14: Gauge Corner Shell Exhibited, Following Grinding in October 1986, by NSC Superrails Located in the High Rail Position of the 8.5° Test Curve

Figure 15: Typical Spalling and Flow Exhibited by AWC Low Alloy Rail Located in the Low Rail Position in the 8.5° Test Curve (October, 1987)

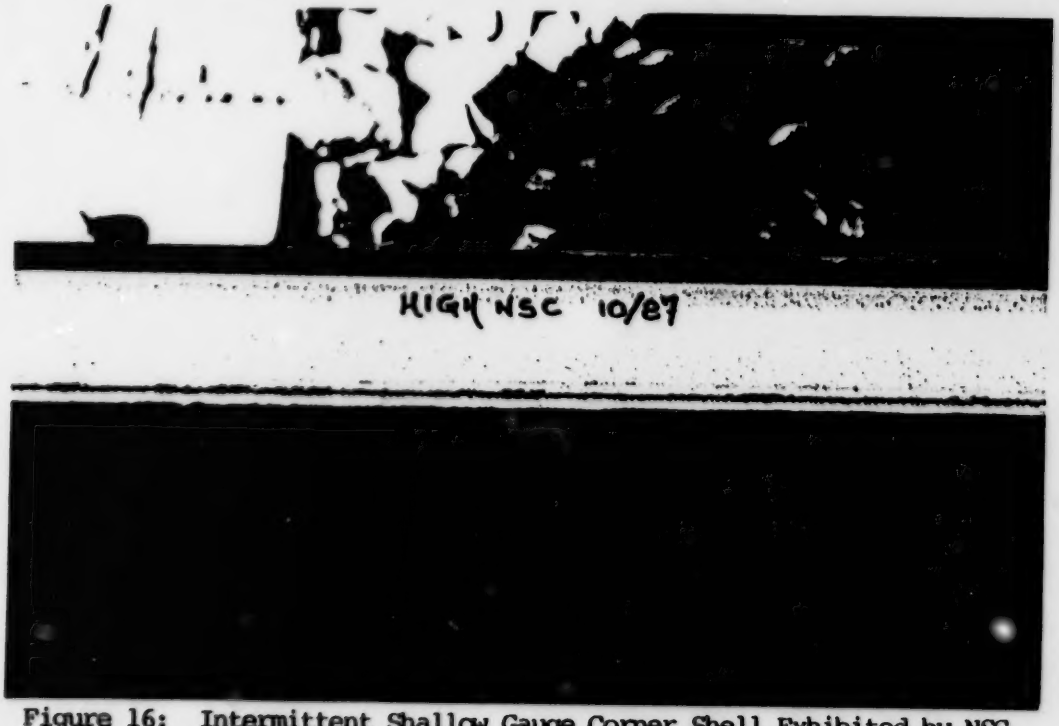

Figure 16: Intermittent Shallow Gauge Corner Shell Exhibited by NSC Superrails Located in the High Rail Position in the 8.5° Test Curve (October, 1987)

IN-SERVICE EVALUATION OF NKK-AHH RAIL

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November, 1987

SUMMARY

Head-hardened alloy rail (AHH rail) produced by Nippon Kokan K.K. as installed, together with NSC Superrail, in four test curves on the Pacific Region of CP Rail in July, 1985. The in-service performance of the NKK-AHH rail was evaluated, in relation to NSC Superrail, using data obtained with the Research and Development Department's rail profilometer. Qualitative field observations were also periodically made to evaluate the relative susceptibilities of these rails to surface defect formation.

The NKK and NSC rails both exhibit excellent resistance to metal loss (i.e. metal lost from the original profile due to the combined actions of wear, flow and grinding). For both high and low rail positions in the fully developed sections of curves, there were only marginal differences in the amounts of metal loss experienced by comparably located NKK and NSC rails (based on the last profile measurements taken in October, 1987). Further, neither trial rail was consistently superior to the other trial rail. The amounts of metal loss experienced by the trial rails, and their predicted service lives, varied with the test curve. However, the range of projected service lives of NKK and NSC rails within the four test curves was quite similar (NKK: 3.8-16.8 years, NSC: 4.0-16.8 years).

The NKK and NSC rails both exhibit acceptable resistance to surface defect formation. Significant surface damage has been experienced in only one of the four test curves, and in that curve both trial rails exhibited surface defects after only three months of service (10.9 MGT -- this test site is in a double track region and receives only loaded traffic). This surface damage increased in severity, particularly on the NKK rail, and necessitated corrective grinding after 51.5 MGT. The corrective grinding treatment did not wholly remove these surface defects, but the residual defects have not significantly progressed. This particular test curve has a very severe grade (-2.30%, westbound) and loaded trains brake heavily over this section of track. Historically, Algoma 1.2% Cr rails in this curve have had to be replaced after as little as 18 months of service.

On the basis of in-service performance, the NKK-AHH rail is a viable alternative to the NSC Superrail in premium rail applications.

SOMMAIRE

La performance en service de deux rails, le rail en acier allié à champignon durci (AHH) de la Nippon Kokan K.K. et le "Superrail" de la NSC, a été comparée en juillet 1985 dans quatre voies en courbe du réseau CP - Région du Pacifique. L'étude comparative a été réalisée à l'aide du profilomètre mis au point par le service Recherche et Développement du CP. Des observations périodiques ont également été faites afin de déterminer la susceptibilité relative de ces deux rails aux avaries de surface.

Les deux rails, NKK et NSC, ont affiché une excellent tenue à l'usure (c'est-à-dire une faible réduction de la section par usure, écoulement plastique et meulage par rapport au profil d'origine). Les deux types de rails posés en file extérieure et intérieure ont connu, en milieu de courbe et en position comparable, des taux de réduction de section quasiment identiques, d'après les résultats des derniers contrôles profilométriques réalisés en octobre 1987. Mais, en fait, aucun des deux rails ne s'est révélé supérieur à l'autre de manière constante. Les taux d'usure et les prévisions de durée de vie utile restante ont varié dans chaque cas d'un site d'essai à l'autre. Par contre, les fourchettes des durées de vie restante prévues sur l'ensemble des sites

d'expérimentation sont à peu de choses près identiques (NKK: de 3,8 à 16,8 ans et NSC: de 4,0 à 16,8 ans).

Les deux rails, NKK et NSC, affichent une résistance aux avaries de surface acceptable. Des avaries non négligeables de ce type ne sont apparues qu'à un seul site d'expérimentation, celui-ci se trouvant dans une région à double voie et écoulant exclusivement des trains chargés. Les deux rails ont montré des signes d'avaries de surface après seulement trois mois de service (10,9 MTB), avaries qui ont empiré, particulièrement sur le rail NKK, au point de nécessiter un meulage correctif dès après 51,5 MTB. Ce meulage n'a pas résussi à éliminer complètement les avaries de surface, mais il a permis d'en tenir la progression à une valeur négligeable. Le site d'expérimentation qui a fait problème accuse une pente très marquée (-2,3% en direction ouest), les trains chargés étant obligés de freiner lourdement. Pour fixer les idées, rappelons que les rails Algoma à 1,2% de Cr n'y ont duré que 18 mois.

A la lumière des performances constatées, il est permis d'affirmer que le rail NKK-AHH peut avantageusement remplacer le "Superrail" de la NSC dans les endroits difficiles.

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1.0 INTRODUCTION

Head-hardened alloy rail purchased from Nippon Kokan K.K. of Japan was installed, along with NSC Superrails, in four test sites on the Pacific Region of CP Rail in late July, 1985. This rail, referred to as NKK-AHH rail, is 136 lb./yd. and is produced by two-stage flame heating and slack-quenching. It resembles the NSC Superrail in microstructure and mechanical properties.

This report presents the results of in-service testing of the NKK-AHH rail in relation to NSC Superrail (as well as to adjacent, service-worn, Algoma 1.2% Cr rail sections). Qualitative field observations on the relative susceptibilities of the NKK and NSC rails to surface defect formation are noted. Descriptions of the test locations and method of data acquisition and analysis are included.

2.0 TEST SITES AND MEASUREMENT POINTS

The four test sites on the Pacific Region are:

Site 9A - Mile 79.5, Mountain Subdivision
Site 9B - Mile 92.2, Mountain Subdivision
Site 9C - Mile 63.3, Mountain Subdivision
Site 9D - Mile 72.2, Mountain Subdivision

Details of the physical and metallurgical properties of the rail steels involved in this study [1-3] are listed in Table 1; track characteristics are summarized below.

TRACK

TYPE:	Site 9A: single track Site 9B: double track (north track contains trial rails and experiences only loaded traffic) Site 9C: single track Site 9D: double track (south track contains trial rails and experiences only loaded traffic)
GEOMETRY:	High and low rails of fully developed sections of curves ranging in curvature from 6.00 to 10.50 degrees and in length from 150 to 450 feet. Spirals and tangents of various lengths.
WELDING PRACTICE:	Continuously flash-butt welded rail with mechanical joint bars connecting different rail types.
TIES:	Wood.
SUPERELEVATION:	From 0.00 to 3.50 inches for tangent and spiral sections and 2.00 to 3.50 inches for fully developed sections of curves.
GRADE:	Site 9A: + 0.90%, westbound Site 9B: - 2.30%, westbound Site 9C: 0.00%, westbound Site 9D: + 2.30%, westbound
LUBRICATION:	Trackside lubricators, molybdenum-disulphide based grease.
AXLE LOAD:	Approximately 32.5 tons maximum.
TRACK SPEED:	20-35 mph.
ANNUAL TRAFFIC:	Sites 9A and C: approximately 60 MGTs Sites 9B and D: approximately 45 MGTs

Measurements of track curvature, superelevation and gauge were taken at the four NKK-AHH rail test sites immediately following installation of the trial rails in July '85, and points of wear measurement were then selected. These track measurements were repeated in October '85, September '86, April '87 and again in October '87, and confirmed that there had been no significant changes to the test sites over the course of the evaluation program. The September '86 track measurements for test sites 9A-D are shown in Figures 1-4, respectively. Distances are given in terms of 31-foot stations, commencing at the tangent track on the east side of each test curve. Information on the traffic passing over these sites was supplied by the Chief Statistician, CP Rail.

A total of 64 relative metal loss measurement points were selected on the four NKK-AHH rail test sites, all located at the change-over points from one rail type to another. Twenty-eight of these points are located in the fully developed sections of curves, twenty are on tangent track sections and the remaining sixteen points are on spirals. Possible joint effects required that the measurement points be located several feet from the joint; increments of six feet were allowed for in the present test.

Severe spalling and shelling of both NKK and NSC rails in test site 9B necessitated that this site receive a corrective grinding

treatment in October '86 (51.5 MGTs). Test sites 9A, C and D received preventive grinding treatments in January '87 and again in April '87 (just prior to the April '87 profile measurement program). Profile measurements were not taken before/after any of the above grinding operations; therefore, metal loss due solely to grinding cannot be determined.

3.0 DATA COLLECTION AND ANALYSIS

All metal loss data was collected with the rail profilometer [4] developed by the Research and Development Department, CP Rail and processed on the microcomputer in the department.

Reference profile measurements were taken at the selected measurement points, for all four test sites, in late July '85 within several weeks of the installation of the trial rails. These original profiles, together with subsequent profile measurements, allow for a relative evaluation of NKK-AHH rail based on absolute and/or cumulative metal loss. Subsequent profile measurements were taken at test sites 9A-D in October '85, May '86, September '86, April '87 and again in October '87. Qualitative field observations of the surface defects exhibited by the trial rails were made during each series of profile measurements.

A new mounting system for the profilometer was developed in early 1986 and was first incorporated into the profile measurement system in the May, 1986 profile measurement program. The existing data collection equipment was replaced with a battery data logger [5] in late 1986; this data logger was first used in the September, 1986 profile measurement program.

For each profile comparison, three measurements of relative metal loss are reported. These are: vertical head loss, loss at the gauge face and reduction in head area. The vertical and gauge face losses are calculated in accordance with standard practice [6], as shown in Figure 5. The area calculations consider as lost material which has been removed from the rail head by wear and grinding, along with material which has flowed outside the original profile. The resolution limit of the profilometer for vertical and gauge face loss is 0.004 inches, and 0.016 square inches for total head area loss. For profile matching purposes, a difference of 0.008 inches has been specified as the minimum difference required to constitute significant vertical and/or gauge face loss; 0.031 square inches has been specified for total head area loss comparisons. All metal loss data were generated by matching a given profile to its corresponding reference profile measurement.

The Algoma 1.2% Cr rails included in this study were originally rolled to the AREA 136RE section; however, these rails have been in

track for up to five years. These Cr rails are work-hardened and exhibit worn "reference" profiles. Their performance cannot be equated with that of newly installed Cr rails. These Cr rail profile measurements are included solely to indicate the relative severity of metal loss occuring at each test site.

The NKK-AHH rails and NSC Superrails are also AREA 136RE sections, and their metal loss performance is directly compared. Accordingly, characteristic metal loss trends are based on the amount of metal loss experienced by the trial rails.

4.0 RESULTS AND CONCLUSIONS

The four test sites differ in the magnitude of metal loss, and severity of surface defects, experienced by similar rail types and rail locations. This is expected since each test site is characterized by different track alignment, grade, dynamic loading conditions, braking practices and lubrication. In particular, test site 9B is characterized by a necessarily harsh braking practice because of its large negative grade (-2.30%, westbound). Comparatively mild braking practices are employed in test sites 9A, C and D where the grades range from 0.00% to +2.30%, westbound. Data collected from different test sites have not been directly compared.

As of October '87 the trial rails had been in service for over two years. Experience with other premium rails [2,7,8] suggests that stable wear (not necessarily metal loss) rates should have been achieved after, at most, 100 MGTs. This 100 MGTs figure typically corresponds to both loaded and empty traffic. Test sites 9A and C receive both loaded and empty traffic and have experienced $^{+}$130 MGTs as of October '87. Test sites 9B and D receive only loaded traffic and have experienced approximately 100 MGTs over the same period. The trial rails in test sites 9A-D do not exhibit stable metal loss versus tonnage patterns. This is believed due to a lack of scheduling coordination between grinding treatments and profile measurement programs. It is assumed that sufficient tonnage has passed over the four test sites for a comparison of the NKK and NSC rails on the basis of cumulative metal loss and resistance to surface defect formation. These comparisons are reported below.

4.1 Metal Loss Analysis

The metal loss versus tonnage variations for all the measurement points in test sites 9A-D are listed in Tables 2-5, respectively. Table 6 presents the average amounts of metal loss, as of October '87, experienced by NKK and NSC rails located in the fully developed curve sections of the four test sites.

The NKK and NSC rails both exhibit excellent metal loss resistance. There are only marginal differences in metal loss between the trial rails as of October '87 (see Table 6), and neither trial rail exhibits consistent superiority over the other trial rail.

Relative service life predictions were made for the trial rails in the fully developed portions of the various test curves by extrapolating their averaged rates of metal loss, up to the point where the high rail becomes condemnable. The accuracy of this predictive approach increases with increasing metal loss. For purposes of analysis, a 20% loss of total head area was selected as the condemning criteria*. For the given test conditions, the projected service lives of the trial rails are as listed in Table 7. There is significant variation from site to site for similar rail types (eg. 15.8 vs. 3.8 years for NKK rails in test sites 9C and D, respectively); however, the projected lives of the trial rails within each test site are quite similar.

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* Such an approach is overly simplistic in that an infinite number of worn profiles can exhibit a 20% loss of head area, and only some of these profiles would be condemnable. In reality, various combinations of vertical and gauge face loss can determine the service life of a rail. These combinations are determined by considerations of allowable lateral clearances, possible impacting between worn wheels and rail joint bars, and beam strength. A maximum head area loss approach, while simplistic, is valid on a comparative basis between the trial rails.

4.2 Surface Defects

Neither the NKK nor the NSC rails have experienced significant plastic flow or surface damage, as of October '87, in test sites 9A or C.

Low rail spalling and isolated high rail gauge corner shell was first observed on test site 9B NKK rails near welds in October '85 (10.9 MGTs). This damage progressed with increasing tonnage, and necessitated the corrective grinding of test site 9B in October, 1986 (51.5 MGTs). Corresponding high NSC rails did not exhibit any defects. Low NSC rails exhibited minor spalling near welds in October '85 (10.9 MGTs). This spalling progressed more slowly than that of the NKK rails and would not have, by itself, necessitated corrective grinding in October '86 (51.5 MGTs). The corrective grinding treatment removed the shallow gauge corner shell defects from the NKK rails but did not wholly remove the low rail surface defects from either trial rail. Figures 6 and 7 illustrate that these defects have not progressed in severity, as of October '87.

The early and significant surface damage experienced by the trial rails in test site 9B is due to its severe grade (-2.30%, westbound), and the likelihood that loaded trains are heavily braking while travelling through the test site. Previous Algoma 1.2% Cr rails have had to be replaced after as little as 18 months service in this test curve.

An isolated case of low rail spalling was first observed on a low NKK rail in test site 9D in October '87 (104.6 MGTs). This damage (see Figure 8) is contained within a six-foot length of rail and is directly opposite a mechanical joint bar. Figure 8 also illustrates that significant tie plate movement occurs in this location, with resulting dynamic wide gauge estimated to be 0.50-0.75 inches. Experience suggests that spalling and flow are significantly worsened by track $\geq$ 0.50 inches over gauge.

Trial rails in test sites 9A-D are scheduled to receive a preventive grinding treatment in late October '87.

Both trial rails exhibit acceptable resistance to surface damage.

5.0 RECOMMENDATIONS

- On the basis of in-service performance, the NKK-AHH rail is an alternative to the NSC Superrail in premium rail applications.

- Profile measurements at the four NKK rail test sites should be taken periodically, in conjunction with other rail evaluation programs, to confirm the long-term stability of the reported metal loss versus tonnage patterns.

REFERENCES

1. "On the Performance of the Experimental Bainitic Chromium-Molybdenum Rail Steel", H. Ghonem, Research and Development Department, CP Rail, Report No. S739-82, April 1982.

2. "Field Evaluation of the Wear Performance of Japanese Head-Hardened Alloy Rail (NSC Superrail)", K. Griffin, L. Feiter and H. Schrekinger, Research and Development Department, CP Rail, Report No. T-881-85, June 1985.

3. "Technical Data Sheets on NKK-AHH (NK-II) Rail", Nippon Kokan K.K., June 1985.

4. "A Wheel/Rail Profilometer System", G. Izbinsky, H. Schrekinger and H. Soares, Research and Development Department, CP Rail, Report No. T-805-84, February 1984.

5. "A Battery Powered Data Logger and Acquisition System for Rail/Wheel Profile Measurements", H. Soares, H. Schrekinger and L. Feiter, Research and Development Department, CP Rail, taken from the 1984 Track/Train Dynamics Summary Report, July 1985.

6. "Standard Practice Circulars: Track", CP Rail.

7 "Field Evaluation of the Wear Performance of Russian P-65 Rail", K. Griffin, Research and Development Department, CP Rail, Report No. S799-83, December 1983.

8. "Rail Assessment", P. Mutton, C. Epp and S. Marich, taken from the Proceedings of the 2nd International Heavy Haul Railways Conference, Colorado Springs, Colorado, U.S.A., 1982.

Table 1

Comparison of the Physical and Metallurgical Properties of Algoma 1.2% Cr Rail, NSC Superrail and NKK-AHH Rail

Characteristic	Algoma 1.2% Cr (1)	NSC Superrail (2)	NKK-AHH (3)
Type	Cr alloy	head-hardened Cr/Si/Nb alloy	head-hardened Cr/Si/V alloy
Section	AREA 136RE	AREA 136RE	AREA 136RE
Properties			
0.2% YS (ksi)	95	130	114 (min.)
UTS (ksi)	150	192	178 (min.)
Elongation(%)	9	19	10 (min.)
Red. of Area(%)	17	50	N/A
Head-Hardness(BHN)	310	380	380
Steelmaking	BOF, Si-killed	BOF, Si-killed	BOF, Si-killed
Microstructure	fully pearlitic	fully pearlitic	fully pearlitic

Table 2

Cumulative Metal Loss Data for Test Site 9A

Measurement Point and Description*	Measure of Metal Loss	Cumulative Tonnage (MGT)					
		0(Ref.)	15.6	46.4	69.4	107.9	136.4
1, LCr	Vertical(in.)	0	0	0	.012	.028	.035
(spiral into	Gauge Face(in.)	0	0	0	0	0	0
6 degree curve)	Total Area(sq.in.)	0	.015	.012	.016	.070	.075
2, HCr	Vertical(in.)	0	0	.008	.008	.035	.039
(spiral into	Gauge Face(in.)	0	0	0	0	0	0
6 degree curve)	Total Area(sq.in.)	0	.005	.021	.023	.093	.102
3, LNSC	Vertical(in.)	0	0	0	.012	.028	.031
(spiral into	Gauge Face(in.)	0	0	0	0	0	0
6 degree curve)	Total Area(sq.in.)	0	.013	.009	.011	.080	.096
4, LNSC	Vertical(in.)	0	0	0	.008	.024	.028
(spiral into	Gauge Face(in.)	0	0	0	0	0	0
6 degree curve)	Total Area(sq.in.)	0	.014	.031	.038	.096	.110
5, LNSC	Vertical(in.)	0	0	0	.012	.024	.020
(6 degree curve)	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.007	.027	.035	.061	.064
6, HNSC	Vertical(in.)	0	0	0	0	.016	.012
(6 degree curve)	Gauge Face(in.)	0	0	0	0	0	.035
	Total Area(sq.in.)	0	.008	.015	.038	.132	.134
7, LNSC	Vertical(in.)	0	0	.016	0	.035	.043
(6 degree curve)	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.016	.047	.027	.084	.096
8, HNSC	Vertical(in.)	0	0	0	0	.024	.031
(6 degree curve)	Gauge Face(in.)	0	0	0	0	0	.020
	Total Area(sq.in.)	0	.010	.032	.041	.120	.139
9, LNKK	Vertical(in.)	0	0	.020	.016	.031	.043
(6 degree curve)	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.005	.033	.029	.069	.079
10, HNKK	Vertical(in.)	0	0	0	0	.020	.012
(6 degree curve)	Gauge Face(in.)	0	0	0	0	0	.039
	Total Area(sq.in.)	0	.006	.027	.049	.120	.132

Table 2 (Cont'd.)

Cumulative Metal Loss Data for Test Site 9A

Measurement Point and Description*	Measure of Metal Loss	Cumulative Tonnage (MGT)					
		0(Ref.)	15.6	46.4	69.4	107.9	136.4
11, LNKK (6 degree curve)	Vertical(in.)	0	0	.012	.020	.043	.047
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.010	.033	.035	.090	.096
12, HNKK (6 degree curve)	Vertical(in.)	0	0	0	0	.016	.020
	Gauge Face(in.)	0	0	0	0	0	.039
	Total Area(sq.in.)	0	.005	.022	.037	.110	.129
13, Tangent NKK	Vertical(in.)	0	0	0	.012	.024	.024
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.009	.017	.021	.073	.073
14, Tangent NKK	Vertical(in.)	0	0	0	.012	.024	.024
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.008	.020	.037	.076	.068
15, Tangent Cr	Vertical(in.)	0	0	0	0	.028	.031
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.009	.013	.016	.072	.077
16, Tangent Cr	Vertical(in.)	0	0	0	0	.031	.035
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.012	.026	.019	.082	.087

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* The following abbreviations designate the rail position and type particular to each measurement point:

HNSC/LNSC - NSC Superrail on high/low rail of curve.
HNKK/LNKK - NKK-AHH rail on high/low rail of curve.
HCr/LCr - Algoma 1.2% Cr rail on high/low rail of curve.

Table 3

Cumulative Metal Loss Data for Test Site 9B

Measurement Point and Description*	Measure of Metal Loss	Cumulative Tonnage (MGT)					
		0(Ref.)	10.9	32.8	48.9	75.7	95.7
17, Tangent Cr	Vertical(in.)	0	-	.008	.016	.059	.067
	Gauge Face(in.)	0	-	0	0	0	0
	Total Area(sq.in.)	0	-	.049	.055	.196	.212
18, Tangent Cr	Vertical(in.)	0	-	0	0	.051	.063
	Gauge Face(in.)	0	-	0	0	0	0
	Total Area(sq.in.)	0	-	.004	.009	.168	.199
19, Tangent NSC	Vertical(in.)	0	-	0	.008	.043	.055
	Gauge Face(in.)	0	-	0	0	0	0
	Total Area(sq.in.)	0	-	.044	.048	.191	.202
20, Tangent NSC	Vertical(in.)	0	-	0	0	.035	.039
	Gauge Face(in.)	0	-	0	0	0	0
	Total Area(sq.in.)	0	-	.021	.013	.139	.155
21, HNSC (8 degree curve)	Vertical(in.)	0	0	0	0	.063	.071
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.026	.032	.039	.251	.266
22, LNSC (8 degree curve)	Vertical(in.)	0	0	.028	.028	.087	.106
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.011	.064	.066	.270	.287
23, HNSC (8 degree curve)	Vertical(in.)	0	0	0	0	.071	.083
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.021	.033	.045	.268	.293
24, LNSC (8 degree curve)	Vertical(in.)	0	.008	.039	.043	.110	.126
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.021	.081	.092	.317	.323
25, HNKK (8 degree curve)	Vertical(in.)	0	0	0	0	.039	.059
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.024	.042	.052	.212	.253
26, LNKK (8 degree curve)	Vertical(in.)	0	0	.020	.031	.083	.102
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.023	.050	.076	.260	.282

Table 3 (Cont'd.)

Cumulative Metal Loss Data for Test Site 9B

Measurement Point and Description*	Measure of Metal Loss	Cumulative Tonnage (MGT)					
		0(Ref.)	10.9	32.8	48.9	75.7	95.7
27, HNKK (8 degree curve)	Vertical(in.)	0	0	0	0	.067	.075
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.029	.036	.054	.268	.285
28, LNKK (8 degree curve)	Vertical(in.)	0	0	.047	.047	.102	.126
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.032	.114	.124	.322	.353
29, Tangent NKK	Vertical(in.)	0	0	0	0	.063	.063
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.038	.040	.040	.248	.253
30, Tangent NKK	Vertical(in.)	0	0	0	0	.047	.047
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.021	.018	.018	.200	.199
31, Tangent Cr	Vertical(in.)	0	0	0	.020	.067	.075
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.018	.033	.060	.257	.260
32, Tangent Cr	Vertical(in.)	0	-	.012	.016	.075	.079
	Gauge Face(in.)	0	-	0	0	0	0
	Total Area(sq.in.)	0	-	.048	.067	.312	.317

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* The following abbreviations designate the rail position and type particular to each measurement point:

HNSC/LNSC - NSC Superrail on high/low rail of curve.
HNKK/LNKK - NKK-AHH rail on high/low rail of curve.

Table 4

Cumulative Metal Loss Data for Test Site 9C

Measurement Point and Description*	Measure of Metal Loss	Cumulative Tonnage (MGT)					
		0(Ref.)	15.6	46.4	69.3	107.9	136.4
33, LCr (exiting spiral from curve east of test site)	Vertical(in.)	0	.012	.008	.024	.098	.098
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.022	.027	.039	.293	.280
34, HCr (exiting spiral from curve east of test site)	Vertical(in.)	0	0	.008	.016	.091	.118
	Gauge Face(in.)	0	0	0	.016	0	0
	Total Area(sq.in.)	0	.014	.026	.049	.279	.334
35, LNSC (exiting spiral from curve east of test site)	Vertical(in.)	0	0	0	.012	.091	.098
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.012	.032	.050	.299	.297
36, HNSC (exiting spiral from curve east of test site)	Vertical(in.)	0	0	0	0	.106	.114
	Gauge Face(in.)	0	0	.016	0	0	0
	Total Area(sq.in.)	0	.009	.050	.068	.378	.390
37, LNSC (6 degree curve)	Vertical(in.)	0	0	0	0	.008	.016
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.009	.017	0	.063	.071
38, HNSC (6 degree curve)	Vertical(in.)	0	0	0	0	.020	.028
	Gauge Face(in.)	0	0	0	0	0	.028
	Total Area(sq.in.)	0	0	.017	.019	.106	.142
39, LNSC (6 degree curve)	Vertical(in.)	0	0	0	0	.024	.028
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.014	.007	.004	.097	.097
40, HNSC (6 degree curve)	Vertical(in.)	0	0	0	0	.016	.024
	Gauge Face(in.)	0	0	.016	0	0	.028
	Total Area(sq.in.)	0	.007	.010	.023	.087	.120
41, LNKK (6 degree curve)	Vertical(in.)	0	0	0	.008	.024	.035
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	0	.015	.014	.099	.111

Table 4 (Cont'd.)

Cumulative Metal Loss Data for Test Site 9C

Measurement Point and Description*	Measure of Metal Loss	Cumulative Tonnage (MGT)					
		0(Ref.)	15.6	46.4	69.3	107.9	136.4
42, HNKK (6 degree curve)	Vertical(in.)	0	0	0	0	.012	.020
	Gauge Face(in.)	0	0	0	0	0	.047
	Total Area(sq.in.)	0	.016	.024	.016	.102	.142
43, LNKK (6 degree curve)	Vertical(in.)	0	0	0	0	.024	.035
	Gauge Face(in.)	0	0	.016	0	0	0
	Total Area(sq.in.)	0	.007	.020	.004	.087	.100
44, HNKK (6 degree curve)	Vertical(in.)	0	0	0	0	.012	.016
	Gauge Face(in.)	0	0	0	0	0	.059
	Total Area(sq.in.)	0	.008	.007	.023	.112	.138
45, Tangent NKK	Vertical(in.)	0	.008	0	0	.008	.020
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.021	.016	0	.070	.086
46, Tangent NKK	Vertical(in.)	0	0	0	0	.008	.016
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.013	.004	.005	.059	.086
47, Tangent Cr	Vertical(in.)	0	0	0	0	0	0
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.011	.006	.028	.013	.017
48, Tangent Cr	Vertical(in.)	0	0	0	.008	.024	.024
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.008	.010	.011	.094	.095

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* The following abbreviations designate the rail position and type particular to each measurement point:

HNSC/LNSC - NSC Superrail on high/low rail of curve.
HNKK/LNKK - NKK-AHH rail on high/low rail of curve.
HCr/LCr - Algoma 1.2% Cr rail on high/low rail of curve.

Table 5

Cumulative Metal Loss Data for Test Site 9D

Measurement Point and Description*	Measure of Metal Loss	Cumulative Tonnage (MGT)					
		Ø(Ref.)	12.0	35.7	53.2	82.5	104.6
49, Tangent Cr	Vertical(in.)	Ø	Ø	Ø	.008	.047	.055
	Gauge Face(in.)	Ø	Ø	Ø	Ø	Ø	Ø
	Total Area(sq.in.)	Ø	.016	.011	.024	.176	.182
50, Tangent Cr	Vertical(in.)	Ø	Ø	Ø	.012	.059	.059
	Gauge Face(in.)	Ø	Ø	Ø	Ø	Ø	Ø
	Total Area(sq.in.)	Ø	.024	.015	.032	.214	.198
51, Tangent NSC	Vertical(in.)	Ø	Ø	Ø	.008	.047	.051
	Gauge Face(in.)	Ø	Ø	Ø	Ø	Ø	Ø
	Total Area(sq.in.)	Ø	.020	.015	.027	.188	.193
52, Tangent NSC	Vertical(in.)	Ø	Ø	Ø	.016	.035	.051
	Gauge Face(in.)	Ø	Ø	Ø	Ø	Ø	Ø
	Total Area(sq.in.)	Ø	.019	.018	.035	.157	.196
53, LNSC (spiral into 10.5 degree curve)	Vertical(in.)	Ø	Ø	.012	.024	.071	.091
	Gauge Face(in.)	Ø	Ø	Ø	Ø	Ø	Ø
	Total Area(sq.in.)	Ø	.026	.046	.057	.256	.275
54, HNSC (10.5 degree curve)	Vertical(in.)	Ø	Ø	Ø	.024	.098	.142
	Gauge Face(in.)	Ø	Ø	.075	.098	.154	.205
	Total Area(sq.in.)	Ø	.034	.100	.178	.466	.581
55, LNSC (spiral into 10.5 degree curve)	Vertical(in.)	Ø	Ø	.012	.028	-	.094
	Gauge Face(in.)	Ø	Ø	Ø	Ø	-	Ø
	Total Area(sq.in.)	Ø	.017	.030	.055	-	.263
56, HNSC (10.5 degree curve)	Vertical(in.)	Ø	Ø	Ø	.031	.094	.130
	Gauge Face(in.)	Ø	Ø	.075	.083	.134	.185
	Total Area(sq.in.)	Ø	.020	.104	.190	.439	.542
57, LNKK (spiral into 10.5 degree curve)	Vertical(in.)	Ø	.008	.012	.031	.083	.118
	Gauge Face(in.)	Ø	Ø	Ø	Ø	Ø	Ø
	Total Area(sq.in.)	Ø	.025	.028	.073	.260	.317
58, HNKK (10.5 degree curve)	Vertical(in.)	Ø	Ø	.008	.024	.098	.150
	Gauge Face(in.)	Ø	Ø	.083	.102	.142	.201
	Total Area(sq.in.)	Ø	.045	.115	.192	.480	.615

Table 5 (Cont'd.)

Cumulative Metal Loss Data for Test Site 9D

Measurement Point and Description*	Measure of Metal Loss	Cumulative Tonnage (MGT)					
		0(Ref.)	12.0	35.7	53.2	82.5	104.6
59, LNKK (spiral into 10.5 degree curve)	Vertical(in.)	0	0	.024	.039	.087	.114
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.015	.048	.083	.259	.298
60, HNKK (10.5 degree curve)	Vertical(in.)	0	0	.008	.035	.102	.138
	Gauge Face(in.)	0	0	.102	.110	.150	.181
	Total Area(sq.in.)	0	.029	.137	.214	.478	.565
61, LNKK (spiral exiting 10.5 degree curve)	Vertical(in.)	0	0	.008	.028	.063	.094
	Gauge Face(in.)	0	0	.020	0	0	0
	Total Area(sq.in.)	0	.038	.031	.079	.218	.270
62, HNKK (spiral exiting 10.5 degree curve)	Vertical(in.)	0	0	0	.008	.035	.067
	Gauge Face(in.)	0	0	0	.016	.031	.083
	Total Area(sq.in.)	0	.013	.028	.091	.212	.294
63, LNSC (spiral exiting 10.5 degree curve)	Vertical(in.)	0	0	.020	.039	.071	.102
	Gauge Face(in.)	0	0	0	0	0	0
	Total Area(sq.in.)	0	.013	.040	.080	.221	.255
64, HNSC (spiral exiting 10.5 degree curve)	Vertical(in.)	0	0	0	.016	.055	.071
	Gauge Face(in.)	0	0	0	0	.035	.094
	Total Area(sq.in.)	0	.011	.033	.077	.246	.307

---

* The following abbreviations designate the rail position and type particular to each measurement point:

HNSC/LNSC - NSC Superrail on high/low rail of curve.
HNKK/LNKK - NKK-AHH rail on high/low rail of curve.
HCr/LCr - Algoma 1.2% Cr rail on high/low rail of curve.

Test Site	Rail Type	High Rail Metal Loss *			Low Rail Metal Loss *		
		Vertical(in.)	Gauge Face(in.)	Total Area(sq.in)	Vertical(in.)	Gauge Face(in.)	Total Area(sq.in.)
9A	NKK	0.016	0.039	0.131	0.045	0	0.088
	NSC	0.022	0.028	0.137	0.032	0	0.080
9B	NKK	0.067	0	0.269	0.114	0	0.318
	NSC	0.077	0	0.280	0.116	0	0.305
9C	NKK	0.018	0.053	0.140	0.035	0	0.106
	NSC	0.026	0.028	0.131	0.022	0	0.084
9D**	NKK	0.144	0.191	0.590	0.116	0	0.308
	NSC	0.136	0.195	0.562	0.093	0	0.269

* - based on final profile measurements taken in October, 1987.

** - low rail change-over point located in spiral.

Table 6: Average Metal Loss Experienced by NKK and NSC Rails in Fully Developed Sections of Test Curves

Table 7

Service Life Estimates for NKK and NSC
Rails in Fully Developed Sections of Test Curves

Test Site	Projected Service Lives* (MGT/YRS) NSC	NKK
9A	970/16.2	1010/16.8
9B	330/7.3	345/7.7
9C	1010/16.8	945/15.8
9D	180/4.0	170/3.8

* Test sites 9A and C experience approximately 60 MGTs/annum.
Test sites 9B and D experience approximately 45 MGTs/annum.

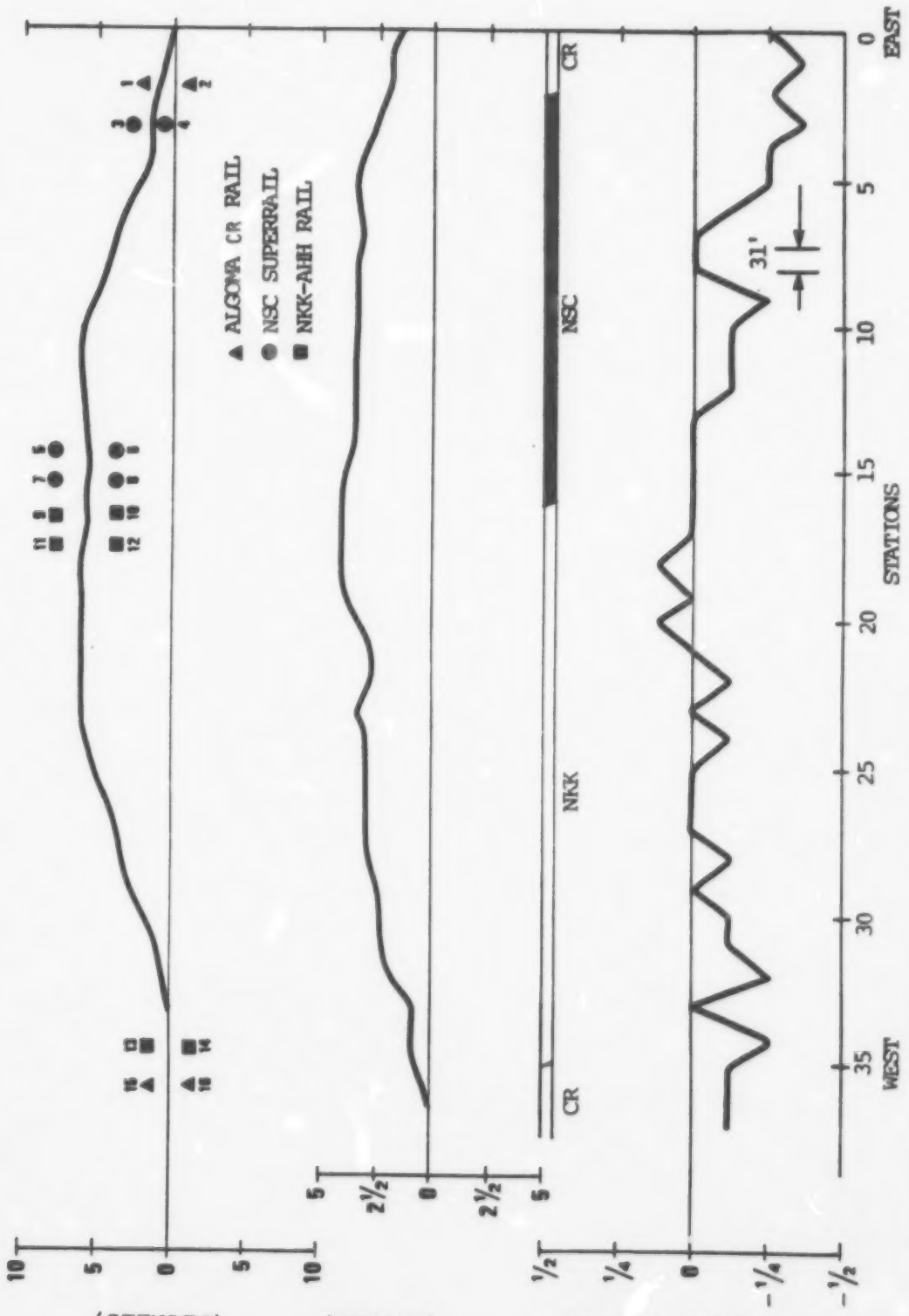

Figure 1: Curvature, Superelevation, Gauge and Location of Measurement Points for NKK Test Site 9A at MP '9.5, Mountain Subdivision

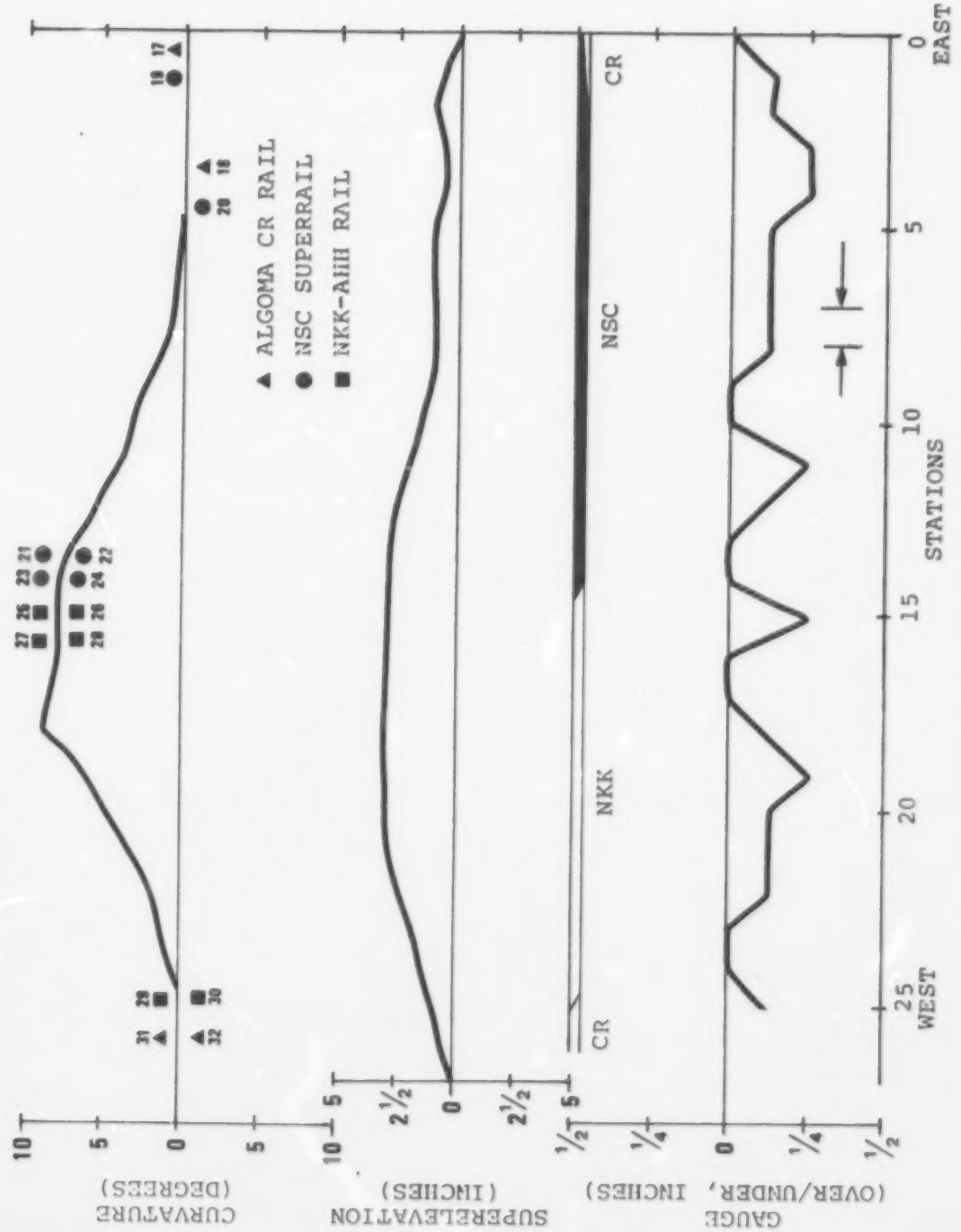

Figure 2: Curvature, Superelevation, Gauge and Location of Measurement Points for NKK Test Site 9B at MP 92.2, Mountain Subdivision

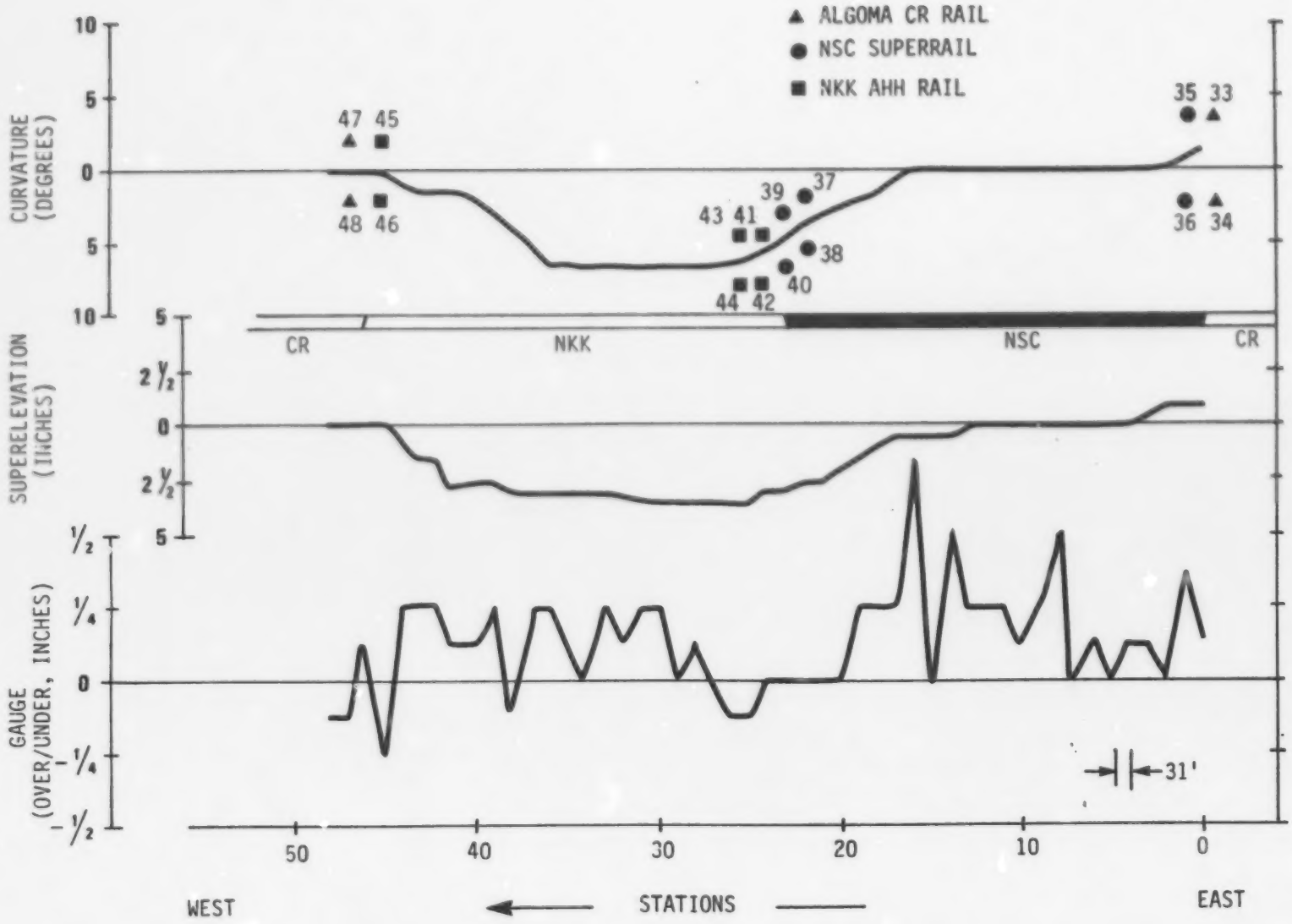

Figure 3: Curvature, Superelevation, Gauge and Location of Measurement Points for NKK Test Site 9C at MP 63.3, Mountain Subdivision

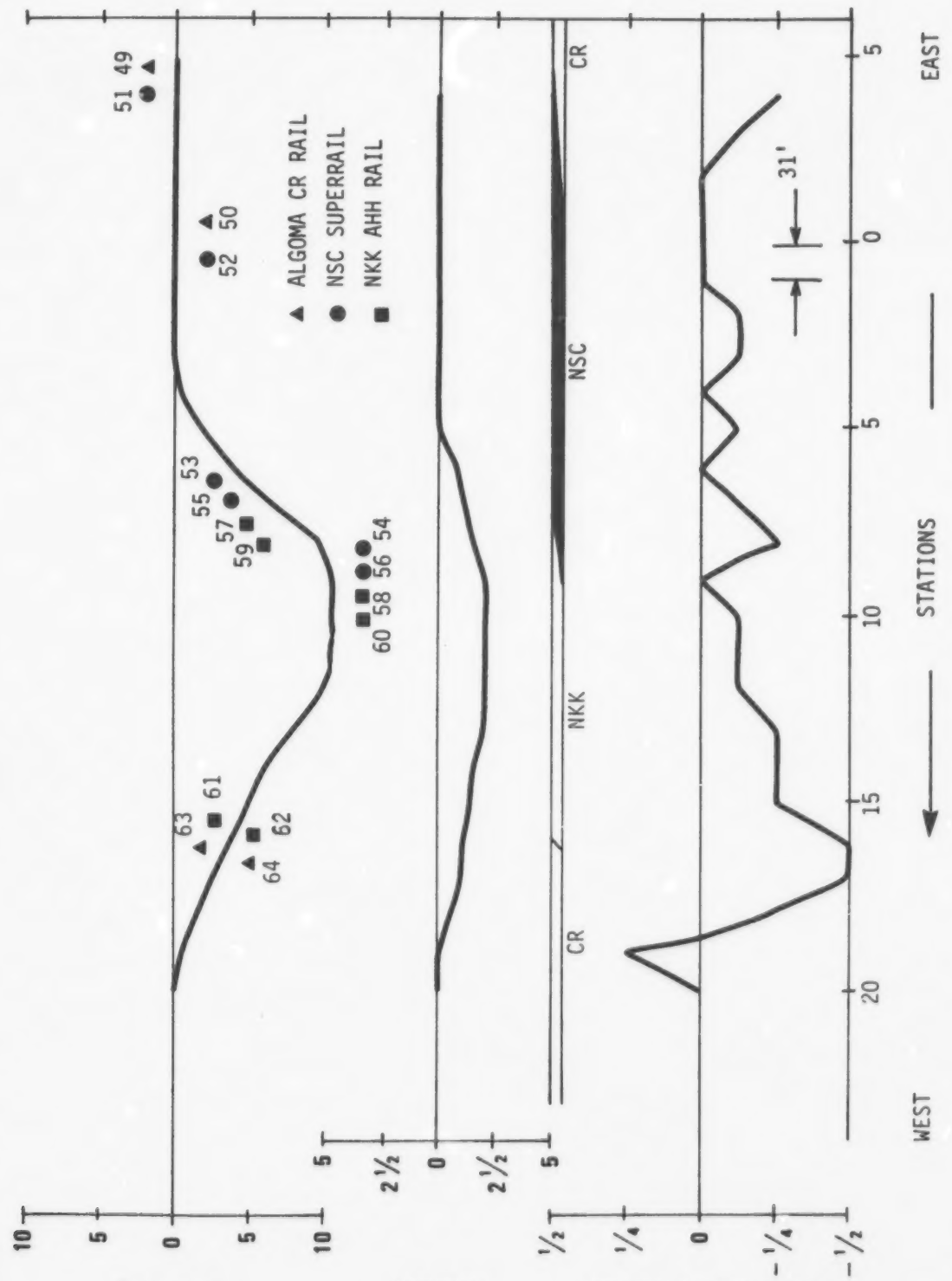

Figure 4: Curvature, Superelevation, Gauge and Location of Measurement Points for NKK Test Site 9D at MP 72.2, Mountain Subdivision

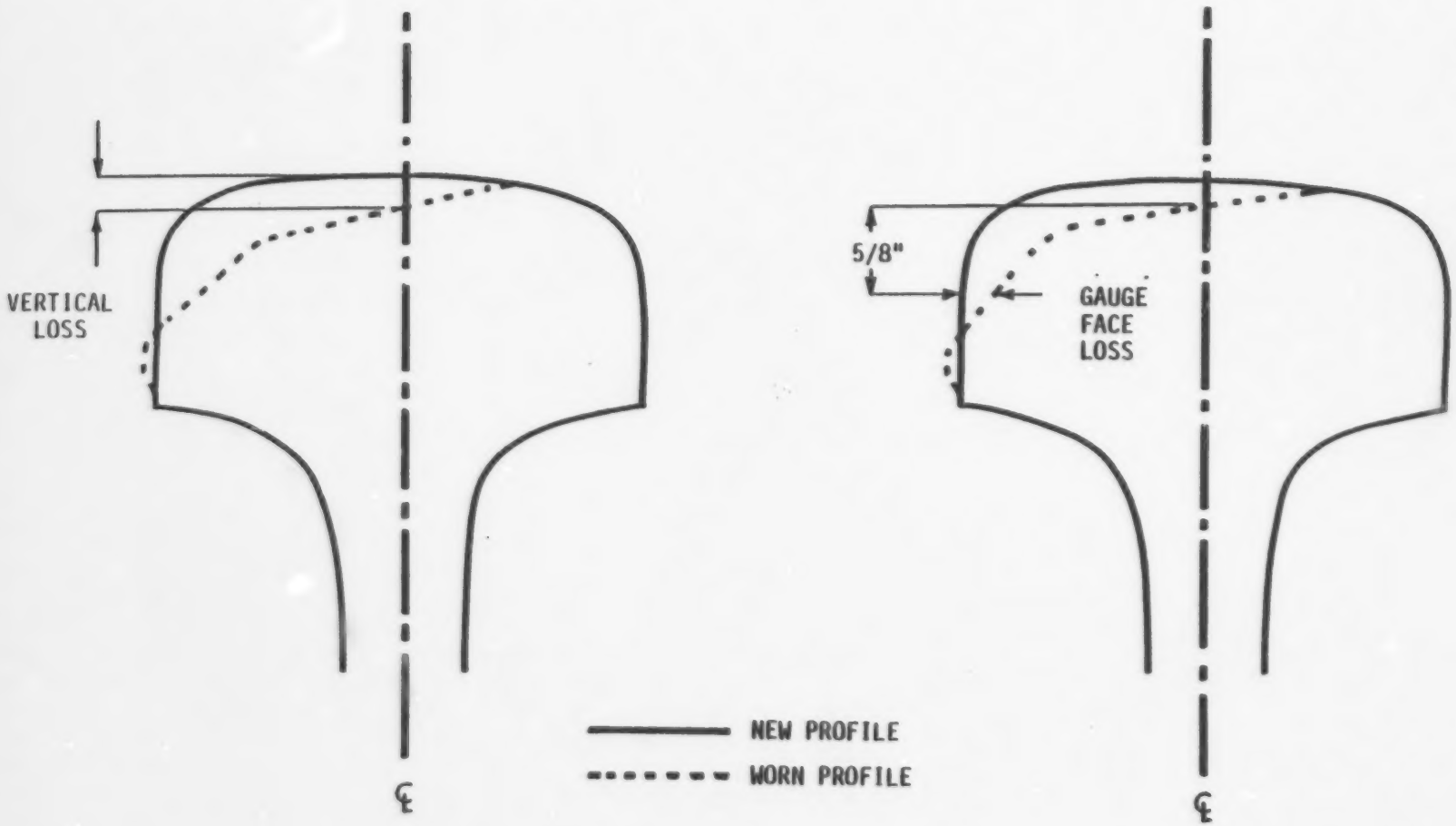

Figure 5: Definition of Vertical and Gauge Face Losses

Figure 6: Typical Spalling and Flow Exhibited by NKK-AHH Rails Located in the Low Rail Position in Test Site 9B (October '87)

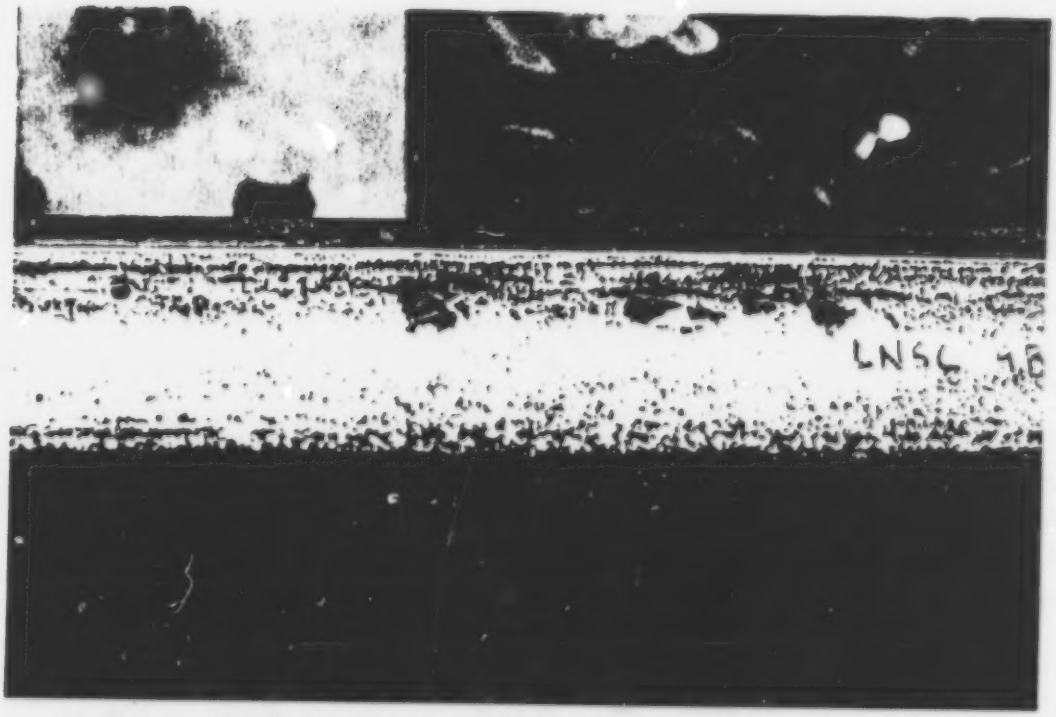

Figure 7: Typical Spalling and Flow Exhibited by NSC Superrails Located in the Low Rail Position in Test Site 9B (October '87)

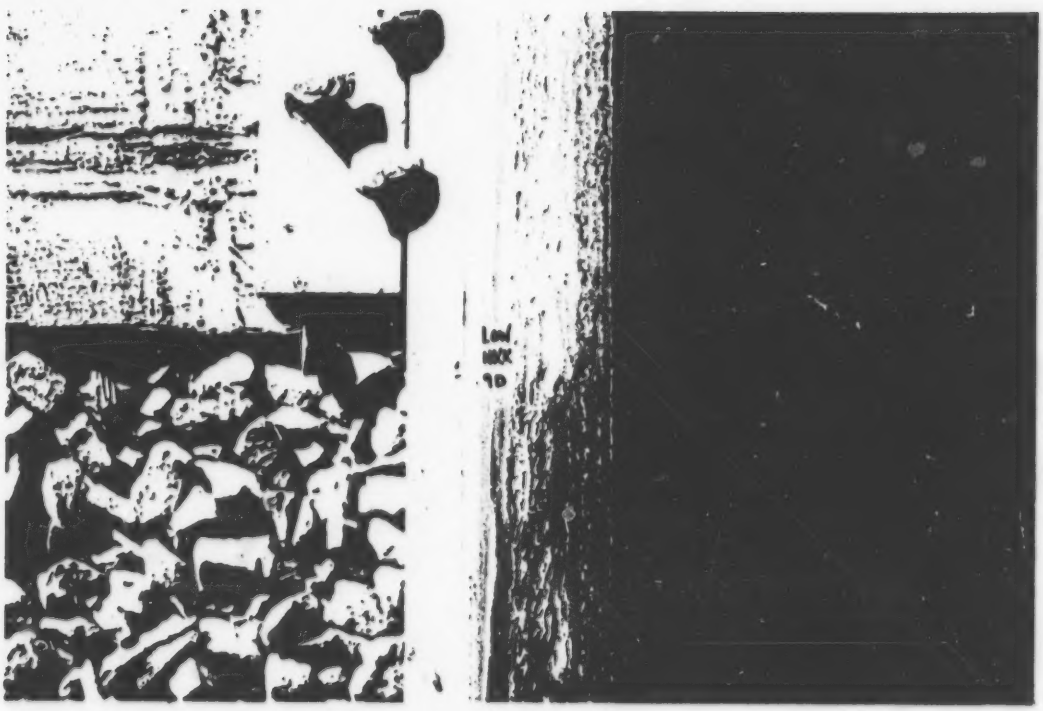

Figure 8: Isolated Spalling and Flow Exhibited by an NKK-AHH Rail Located in the Low Rail Position in Test Site 9D (October '87)

TANGENT TRACK GRINDING TEST
WINCHESTER SUBDIVISION, MP 90.0 TO 100.0

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May, 1988

SUMMARY

Hunting of freight car trucks has been related to rail gauge widening and track misalignment, and ultimately to derailments. The tendency of a rail vehicle to hunt is influenced by many factors, a very significant one being wheel/rail contact geometry. This contact geometry is a function of both wheel and rail profiles. To date, however, research has been concentrated on the influence of the wheel profile.

Testing was conducted during the summer of 1987 to determine the effect of grinding tangent track rails to preselected profiles on the lateral stability of two empty 50-ton piggyback cars. High speed stability tests were conducted over three test sections before and after grinding (one track section received a single-pass grind while the other two sections received two grinding passes). Wheel and rail profiles were also measured, digitized and input to a contact geometry computer program which determined rolling radii differences for the two wheels of a wheelset as a function of wheelset lateral displacement.

Accelerometer data indicated that, for three of the four trucks, tangent track rail grinding either reduced or eliminated truck hunting. The contact geometry program showed that, in most cases, two-pass grinding reduced rolling radii differences when wheels were near flanging.

Three aspects of tangent track profile grinding that should be further examined are:

- optimization of the final rail profile (in conjunction with existing and potential future wheel profiles),
- determination of the duration of this ground profile in service, and
- determination of the effect of rail profile grinding on the stability of 70 and 100-ton car trucks.

SOMMAIRE

L'instabilité transversale (mouvement de lacet) a été reliée au surécartement des rails, au mauvais tracé de la voie et, finalement, aux déraillements. Cette instabilité transversale des véhicules ferroviaires dépend de nombreux facteurs, l'un des plus importants étant la géométrie de contact roue-rail. Cette géométrie est fonction à la fois du profil du rail et de celui de la roue mais, jusqu'ici, les chercheurs ont scruté de beaucoup plus près l'effet du profil des roues que celui du profil des rails.

En été 1987, des essais ont été menés, sur voie en alignement, à l'aide de deux wagons rail-route de 50 tonnes afin de déterminer l'effet du meulage des rails à différents profils préétablis sur la stabilité transversale des véhicules ferroviaires. Le mode opératoire prévoyait un parcours d'essai avant et après meulage, celui-ci étant réalisé à plusieurs endroits en une seule passe et en deux passes ailleurs. De plus, les profils des roues et des rails étaient mesurés, numérisés et introduits dans un programme d'ordinateur qui déterminait pour différents jeux de profils les différences de rayon de roulement des deux roues d'un même essieu, en fonction du déplacement transversal de celui-ci.

L'analyse des signaux accélérométriques enregistrés à l'aide de capteurs placés sur les bogies a révélé que trois des quatre bogies avaient affiché une plus grande stabilité après le meulage des rails. Phénomène confirmé par le programme informatique d'analyse de la géométrie de contact qui a montré que le reprofilage avait eu pour effet, dans la majorité des cas, de réduire les différences entre les rayons de roulement lorsque le boudin des roues touchait presque au champignon du rail.

Trois aspects du reprofilage des voies en alignement devraient être étudiés d'avantage:

- l'optimisation du profil des rails,
- la détermination de la durée de ce profil en service, et
- l'éffet du meulage des rails sur la stabilité transversale de wagons rail-route de 70 et de 100 tonnes.

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1.0 INTRODUCTION

Truck hunting accelerates track deterioration and increases maintenance costs. The tendency of a rail vehicle to hunt is influenced by many factors, a very significant one being wheel/rail contact geometry. This contact geometry is a function of both wheel and rail profiles; however, research to date has been concentrated on the influence of the wheel profile.

High speed stability tests were conducted before and after rail grinding between MP 90-100 on the Winchester Subdivision in August-September, 1987. The results of these tests were supplemented with a wheel/rail contact geometry study using an in-house computer program. The objective of these tests was to examine the effect of tangent track rail grinding on reducing truck hunting.

The test site was ground with a Loram RG9 rail grinder as follows:

MP 90.9 to 96.5 : two grinding passes
MP 96.5 to 97.5 : one grinding pass
MP 97.5 to 100.0 : two grinding passes

Mile 90.0 to 90.9 was not ground and served as a reference zone.

2.0 CAR STABILITY TESTS

High speed (40,50,55 and 60 mph) stability tests were conducted in the westward direction over the test site before, and six weeks after grinding.

2.1 Test Consist and Procedure

The test consist had one locomotive, two empty 50-ton piggyback cars (CP 504244 and CP 504314), the instrumentation car CP 62 and a caboose (see Figure A1).

CP 504314 and CP 504244 were equipped with worn and restored 50-ton trucks, respectively. A worn truck refers to a truck with poor suspension damping, whereas a restored truck has its suspension damping restored to the initial condition. The 50-ton truck has low interaxle shear stiffness in both the worn and restored condition, increasing its propensity to hunt at low speeds.

CP 504244 had slightly worn wheels at the "A" end and near new wheels at the "B" end. Car CP 504314 had slightly worn wheels at the "A" end and very worn wheels at the "B" end.

2.2 Instrumentation

Lateral accelerometers were fixed on the leading axle of each truck.

2.3 Test Results and Observations

Test results are summarized in Table A1.

For each test run, acceleration data (in 'g' levels) along the three test track sections was averaged. These average accelerations (RMS 'g') were obtained from a power spectral density analysis for the hunting frequency range of 1 to 4 Hz. This value represents the average level of lateral oscillation of the truck for each test zone. These results are plotted in Figures A2 to A13. An average acceleration above 0.1 RMS 'g' generally indicates truck instability.

The effect of two-pass rail grinding on car lateral stability varied. It reduced or eliminated hunting for three of the four test trucks. For the truck at the A end of CP 504314, it either made no difference or slightly increased hunting. The reasons for this discrepancy are not known. However, after the test it was noticed that the car body rested on the edge of the center plate rim because the center plate bowl was worn. This condition might have influenced the truck's dynamic behaviour.

Single-pass rail grinding (Mile 96.5-97.5) reduced or eliminated truck hunting for three trucks. For the A end truck of CP 504314 hunting slightly increased.

Due to some track work close to MP 90.0, the tests could not be repeated in the reference zone (Mile 90.0-90.9). Thus, the possible effect on car ride characteristics of any change in wheel/rail adhesion conditions could not be evaluated.

3.0 WHEEL/RAIL MATCHING

3.1 Rail Profile Measurements

Rail profiles were measured at every milepost and half-mile from Mile 90.0 to 100.0. Also, at Mile 93.0 four additional measurements were taken at 10' intervals to compare ground rail profiles. These measurements were taken before and after rail grinding in August and September, 1987, respectively. This information corresponds to 25 different sites for analysis with the wheel/rail matching program.

For each site, left and right rail profiles were measured with the Research rail profilometer, which was equipped with an inclinometer (see Figure 1). Track gauge and superelevation were measured with a high precision gauge specially developed for this study (see Figure 2).

These measurements determined rail profiles and their actual position and angular orientation with respect to each other and to a common coordinate system. The data was recorded with a data logger to be processed later in the Research Laboratory.

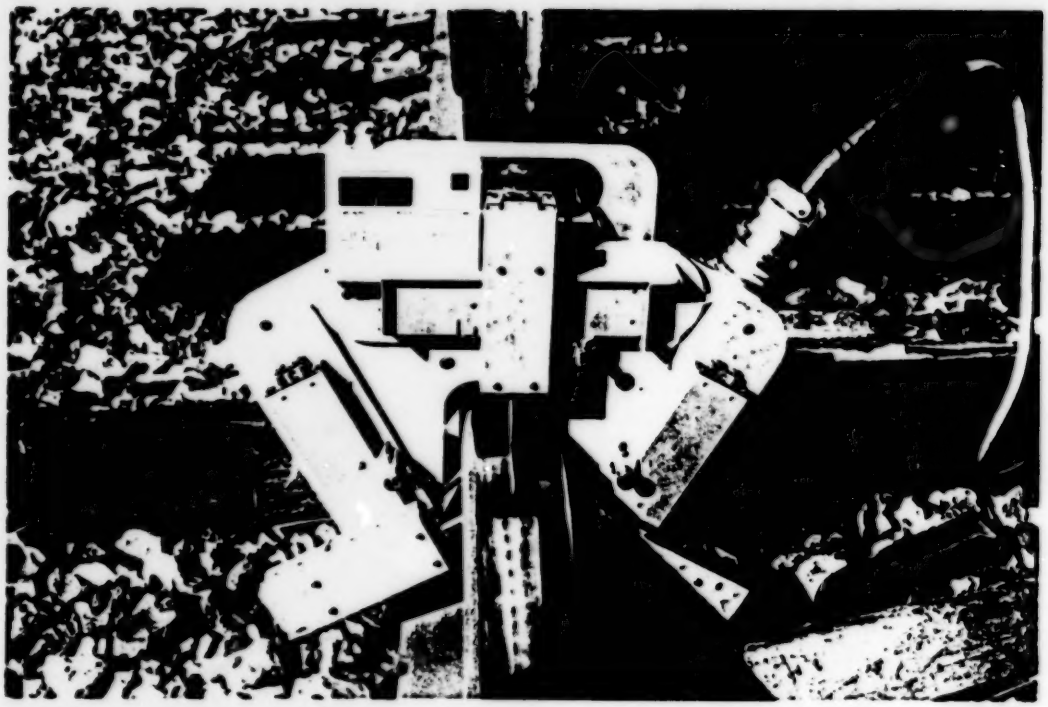


Figure 1: Rail Profile Measurement

Figure 2: Track Gauge Measurement

3.2 Wheel Profile Measurements

Profiles of wheels from cars CP 504244 and CP 504314 were measured in September, 1987, and are presented in Figures A14 and A15.

For each axle, left and right wheel profiles were measured with the Research wheel profilometer (see Figure 3). Back-to-back distance was measured with a high precision gauge (Figure 4) and the inclinometer was used to determine the wheel orientation with respect to the axle. The data was recorded on tape to be processed later in the Research Laboratory.

3.3 Wheel/Rail Matching Program

Data gathered from the measurements described in Sections 3.1 and 3.2 was used as an input to the wheel/rail matching program to examine how grinding affected the rolling radii differences produced by various lateral wheelset displacements.

Rolling radii difference refers to the difference between left and right wheel radii for a specific lateral position of the wheelset. If this difference increases too rapidly for a small lateral wheelset movement, the truck will tend to hunt. For tangent track service, it is therefore important to avoid rapid changes in rolling radii differences within the tread region.

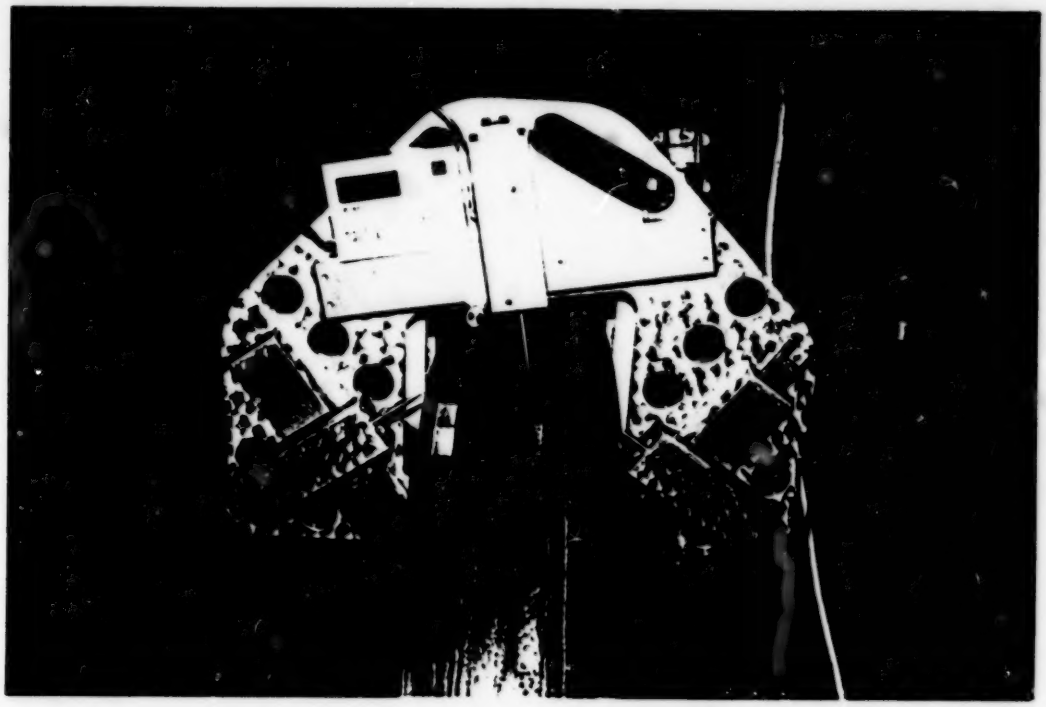


Figure 3: Wheel Profile Measurement

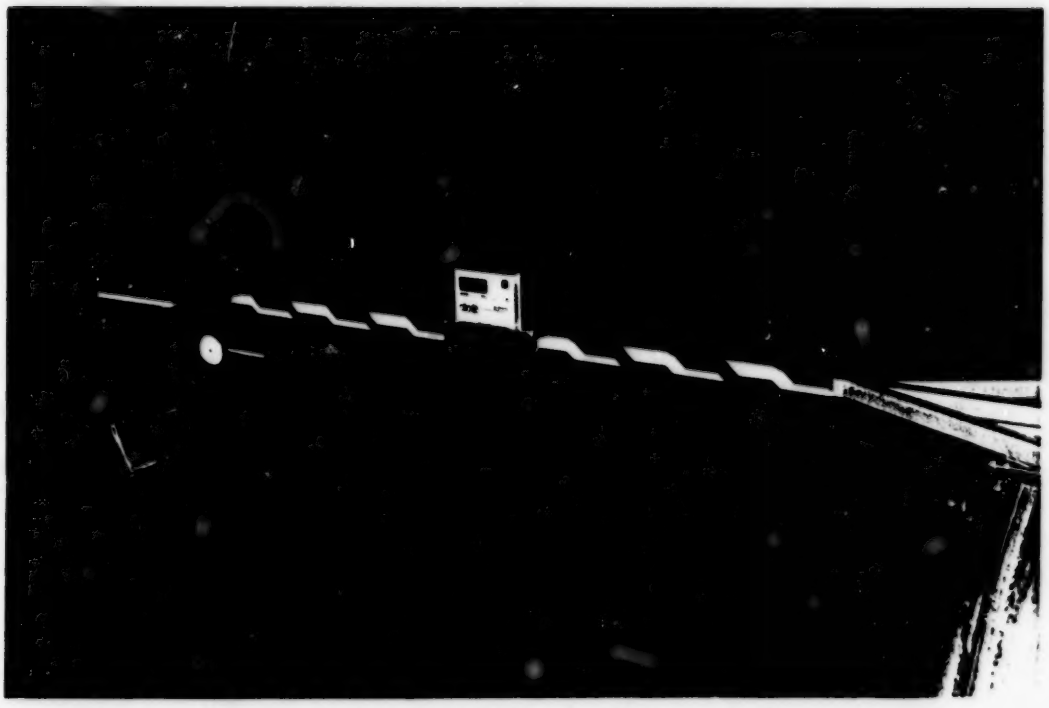


Figure 4: Back-to-Back Wheel Distance Measurement

For each run, data of a particular site, a selected wheelset and a specific lateral position of the wheelset with respect to the track center were input to the program. This information included angular orientation, track gauge and back-to-back wheel distance. The program determined the wheel/rail contact points for left and right wheels. From this, left and right wheel rolling radii were determined. Figures A16 and A17 show typical plots for a wheel/rail match.

The lateral position of the wheelset was then varied to determine the change in rolling radii difference with wheelset lateral displacement. This was done before and after grinding.

3.4 Results and Observations

While it was not feasible to examine in detail all possible wheel/rail profile combinations, representative calculations are presented.

- all axles of car CP 504314 were analyzed using the rail profiles measured at mileages:

    - 94.0 (tangent - ground 2 passes)
    - 97.0 (tangent - ground 1 pass)
    - 99.0 (1.3° curve - ground 2 passes)

- axles 1 and 2 of car CP 504244 were analyzed with the rail profiles measured at Mile 94.0 and 99.0.

In each case the difference in rolling radii between the left and right wheels was plotted (Figures A18 to A22). The vertical axis represents the difference between left and right wheel radii (ΔR). The horizontal axis represents the lateral displacement of the wheelset (ΔY).

A summary of the results at the analyzed mileposts follows:

Mile 94.0: CAR CP 504314 (Figure A18)

After grinding, axles 2, 3 and 4 showed a slight reduction in rolling radii difference when the contact point was close to the flange (where the difference in radii is large).

Axle 1 (B end) showed considerable rolling radii differences for all lateral positions of the wheelset, both before and after grinding. Subsequent examinations revealed that left and right wheels had different profiles.

CAR CP 504244 (Figure A19)

Grinding did not affect the rolling radii differences exhibited by the wheels of axles 1 and 2.

Mile 97.0: CAR CP 504314 (Figure A20)

All wheelsets exhibited a narrower tread contact following grinding, but the rolling radii differences in this region were similar to pre-grinding results.

Mile 99.0: CAR CP 504314 (Figure A21)

As per Mile 94.0.

CAR CP 504244 (Figure A22)

Grinding slightly reduced the rolling radii differences exhibited by the wheels of axles 1 and 2.

4.0 TRACK GAUGE

The majority of sites had 1/8" to 7/16" wide gauge, which accounts for the wide tread contact shown in Figures A18-A22.

5.0 CHARACTERISTICS OF THE GRINDING PATTERN

Rail profiles measured before and after grinding were superimposed to identify characteristics of the grinding pattern.

Rail profiles measured at mileages 94.0, 97.0 and 99.0 are presented in Figure A23 and show that metal removal occurred primarily at the gauge and field corners.

At mileages 94.0 and 99.0 (2 grinding passes) the depth of cut reached 0.070". At mileage 97.0 (1 grinding pass) it reached 0.040".

6.0 CONTACT BAND

The rail heads at MP 96.0, 97.0, 98.0, 99.0 and 100.0 were spray painted following grinding and examined after the passage of the test train (50-60 mph) to determine the rail contact band.

On tangent track (MP 96.0, 97.0, 98.0 and 100.0) the contact band starts at 1 1/8" to 1 5/8" from the gauge corner. Its width varies from 3/8" to 3/4". The wheels are running along the center of the rail head.

On curved track (MP 99.0) the contact band on the high rail starts at 3/4" from the gauge corner and is roughly 1" wide. On the low rail it starts at 1 1/8" from the gauge corner and is 5/8" wide (see Figures 5 and 6).

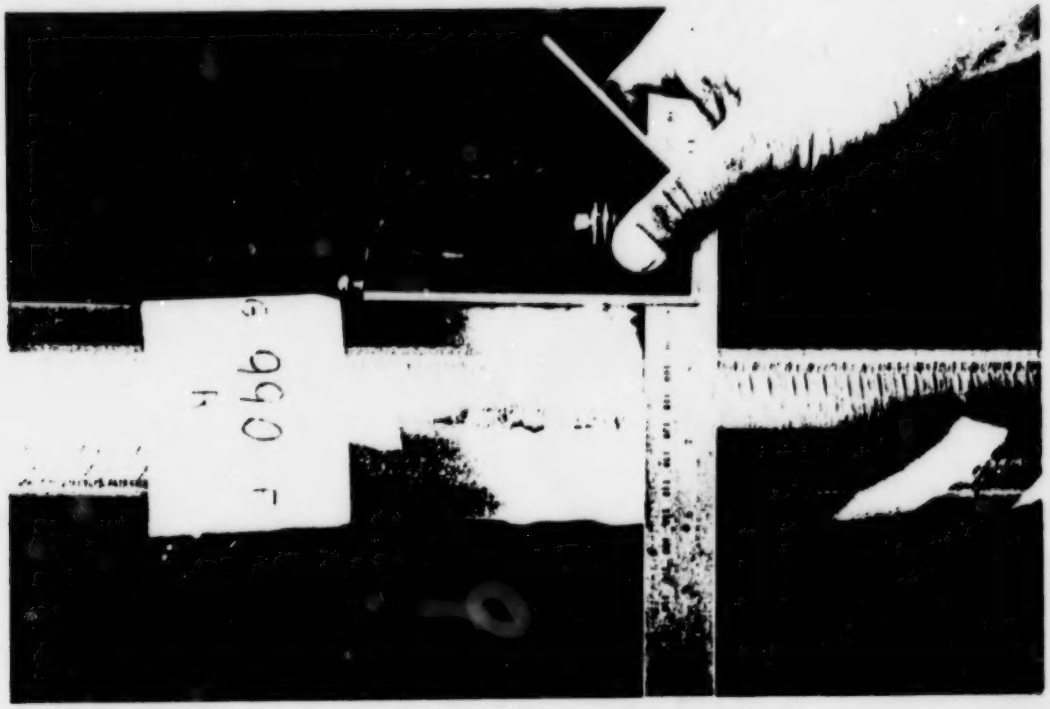


Figure 5: Contact Band on the Low Rail at MP 99.0

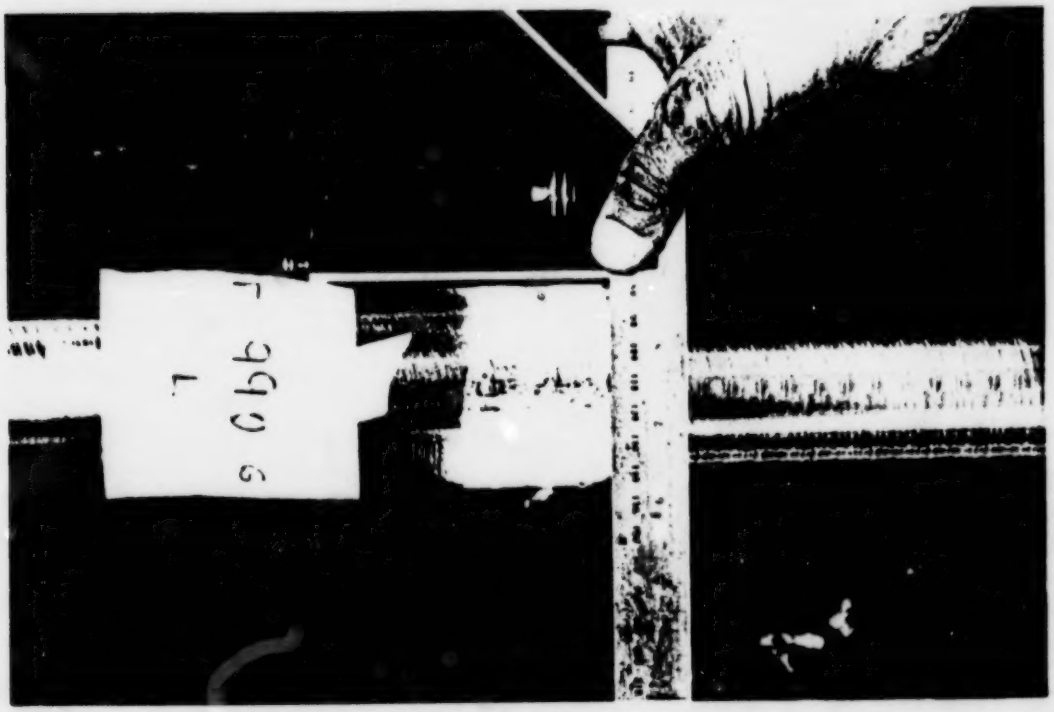


Figure 6: Contact Band on the High Rail at MP 99.0

7.0 CONTINUITY OF GRINDING PATTERN

Four additional rail profile measurements taken around Mile 93.0 at 10' intervals confirmed that the grinding pattern was consistent.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Tangent track rail grinding either reduced or eliminated hunting for three out of four test trucks. Hunting remained the same or slightly increased for the fourth truck.

Two-pass grinding slightly decreased rolling radii differences when wheels were near flanging.

Single-pass grinding had little effect on rolling radii differences in the tread contact region.

It is recommended that further tangent track rail grinding testing be carried out to determine:

- the optimum tangent rail profile (in conjunction with existing and potential future wheel profiles),

- the duration of the grinding effect, and

- the effect of rail profile grinding on the stability of 70 and 100-ton car trucks.

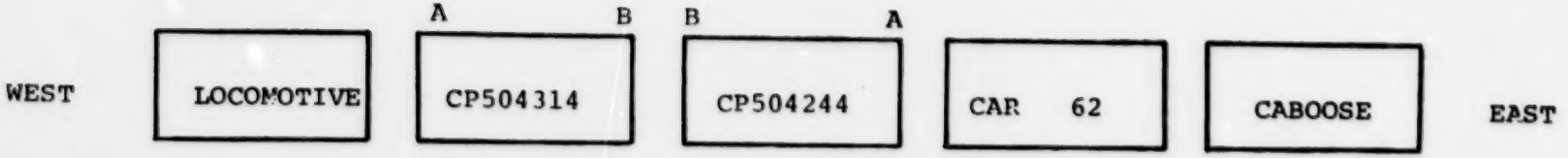
APPENDIX A

Table A1

Car Stability Test Results Before and After Rail Grinding

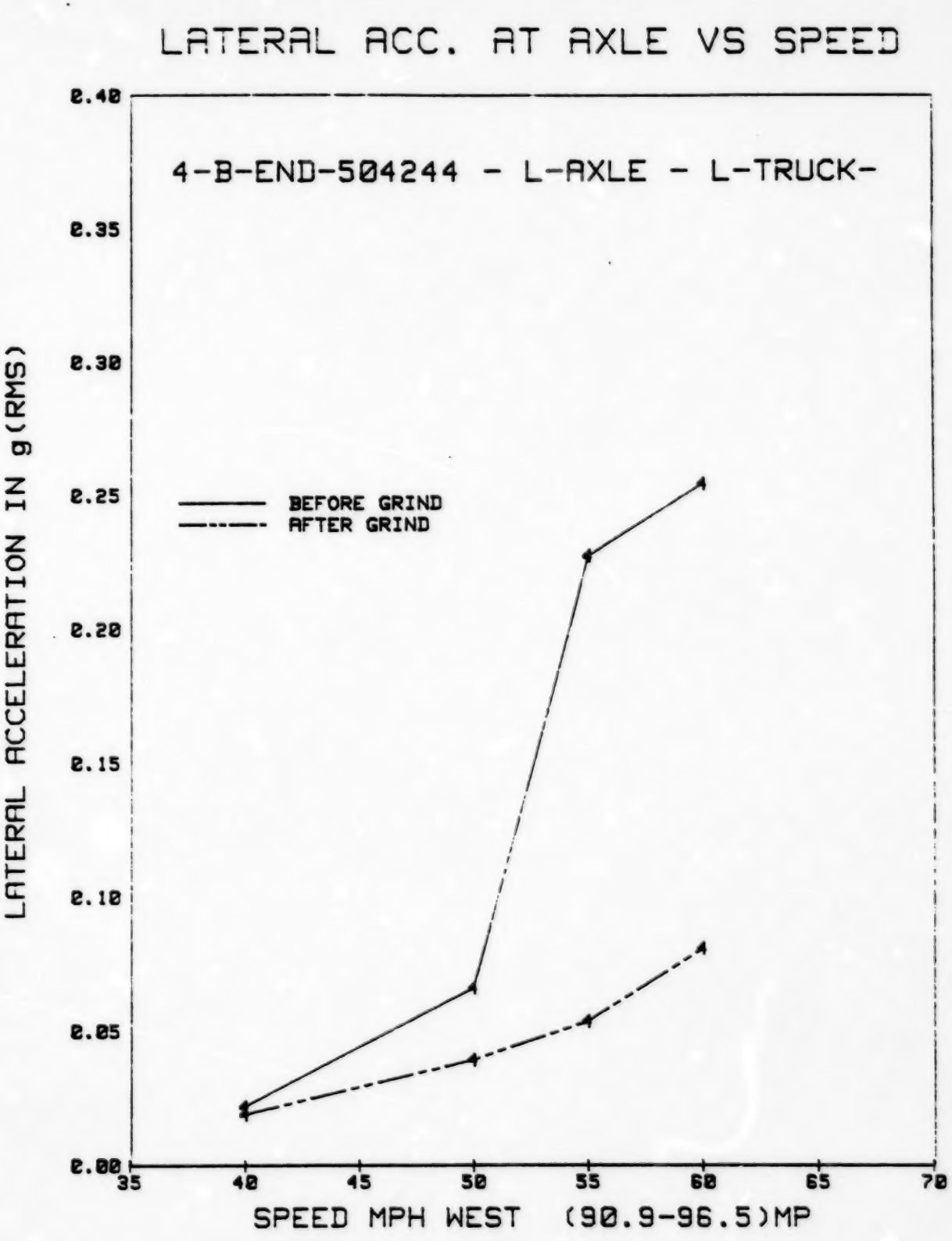
Mileage	90.0-90.9	90.9-96.5	96.5-97.5	97.5-100
	Hunting Speed (mph) and RMS 'g' values at 60 mph			
Grinding Passes	None	2	1	2
Car CP 504244				
'A' end truck Before grinding	>40 0.28	>45 0.26	>45 0.24	>50 0.23
After grinding	- -	>55 0.16	>50 0.23	>55 0.18
'B' end truck Before grinding	>50 0.25	>50 0.26	>50 0.25	>50 0.21
After grinding	- -	Stable 0.08	Stable 0.05	Stable 0.06
Car CP 504314				
'A' end truck Before grinding	>40 0.25	>40 0.25	>40 0.225	>40 0.25
After grinding	- -	>40 0.26	>40 0.28	>45 0.25
'B' end truck Before grinding	>45 0.20	>45 0.22	>50 0.21	>50 0.26
After grinding	- -	Stable 0.08	>50 0.13	>50 0.175

Note: RMS 'g' - root mean square acceleration. It represents the average acceleration over the test zone.
An average acceleration above 0.1 RMS 'g' generally represents truck instability.
A hunting speed >50 means that the truck started to hunt between 50 to 55 mph.



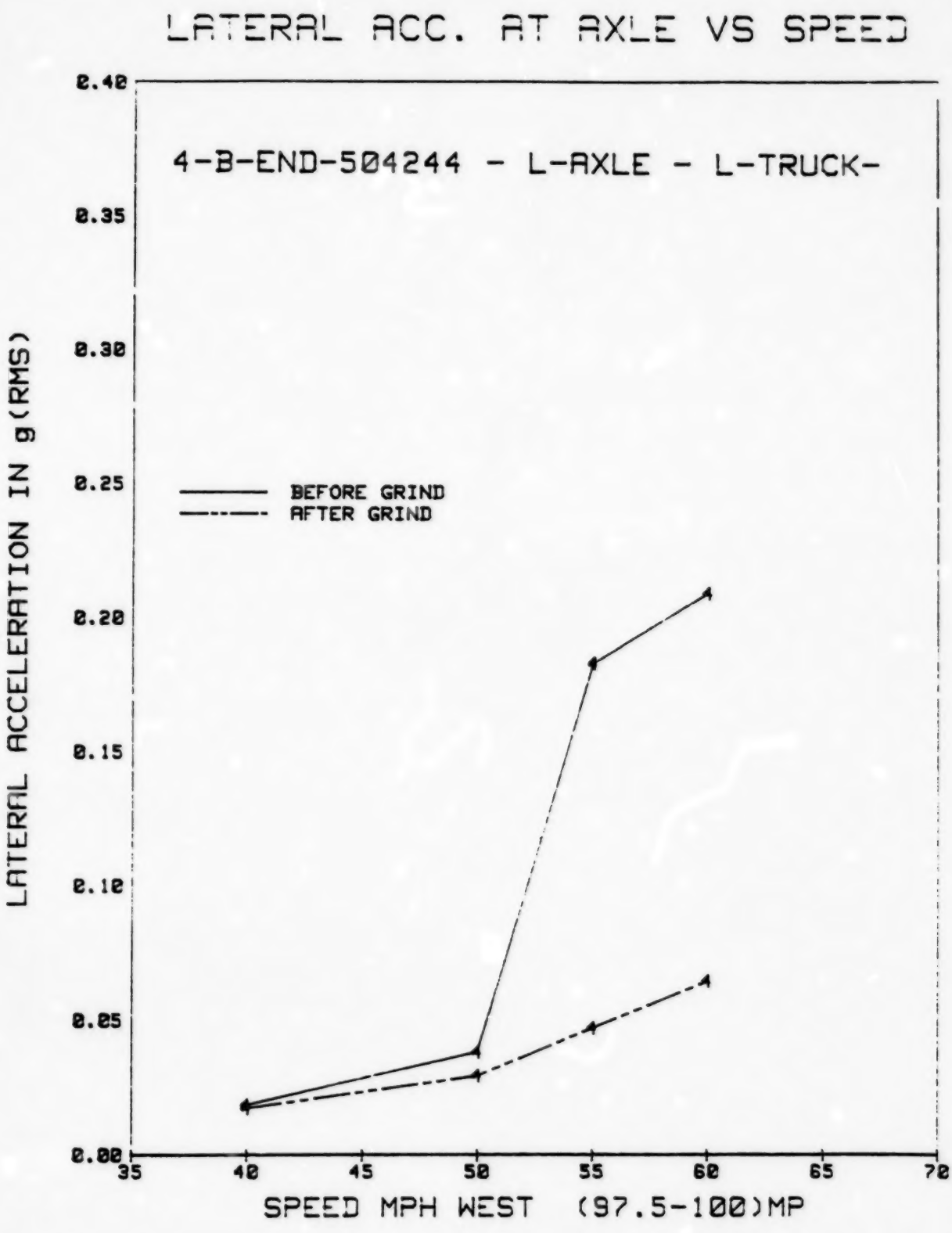
Consist for Car Stability Test

FIGURE A1



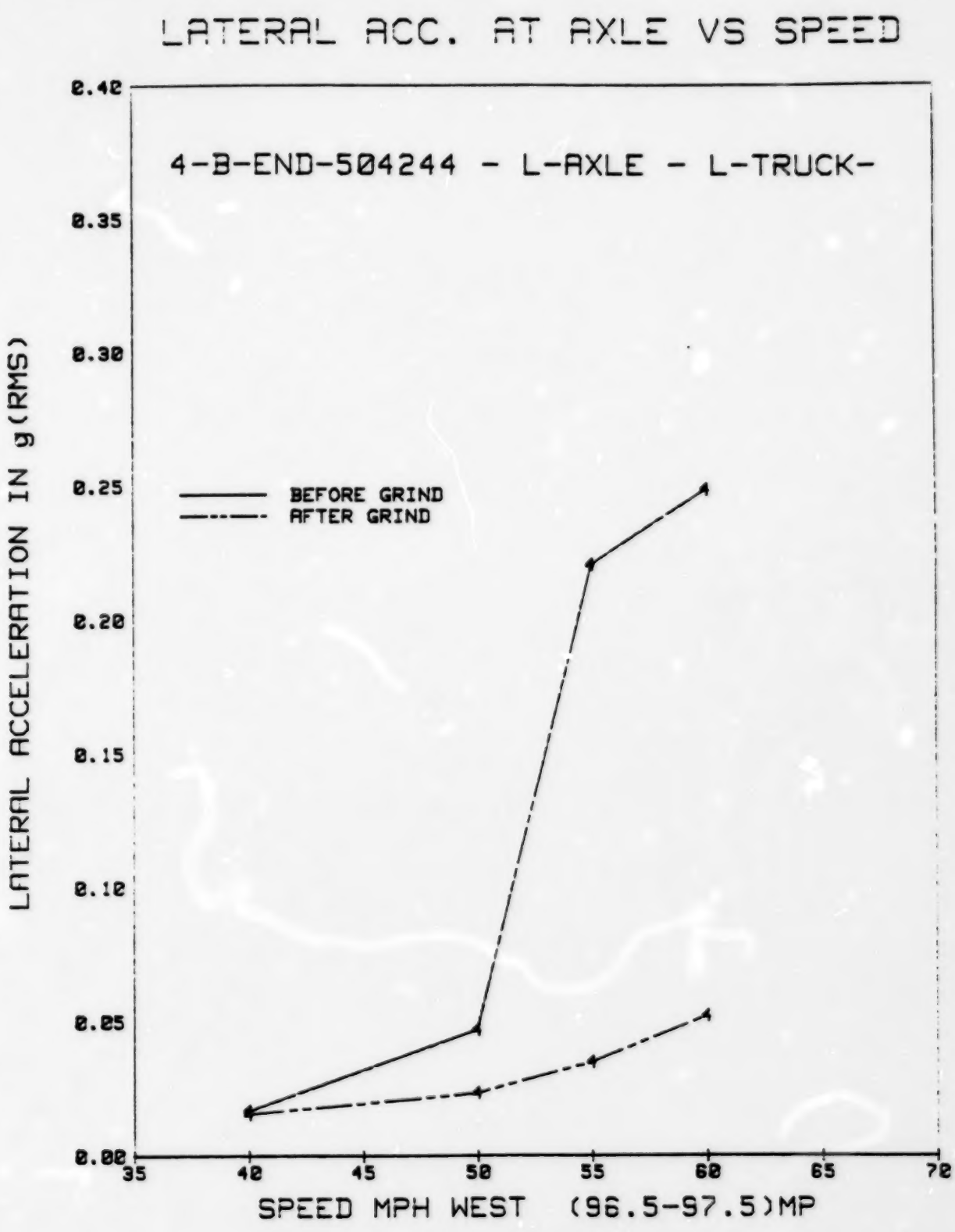
**Lateral Acceleration of CP 504244 -
B End vs Speed from Mile 90.9 to 96.5**

FIGURE A2



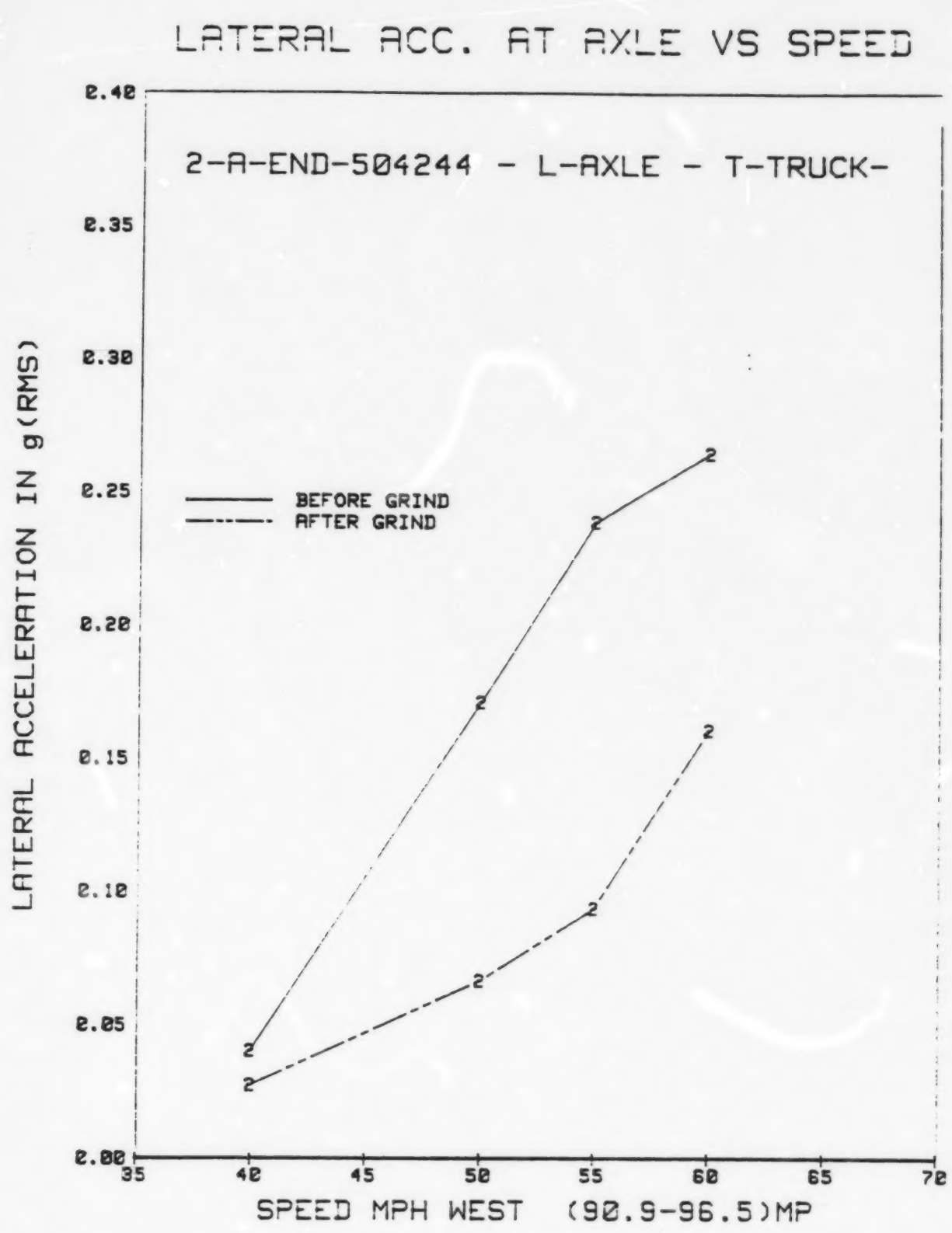
**Lateral Acceleration of 504244 -
B End vs Speed from Mile 97.5 to 100.0**

FIGURE A3



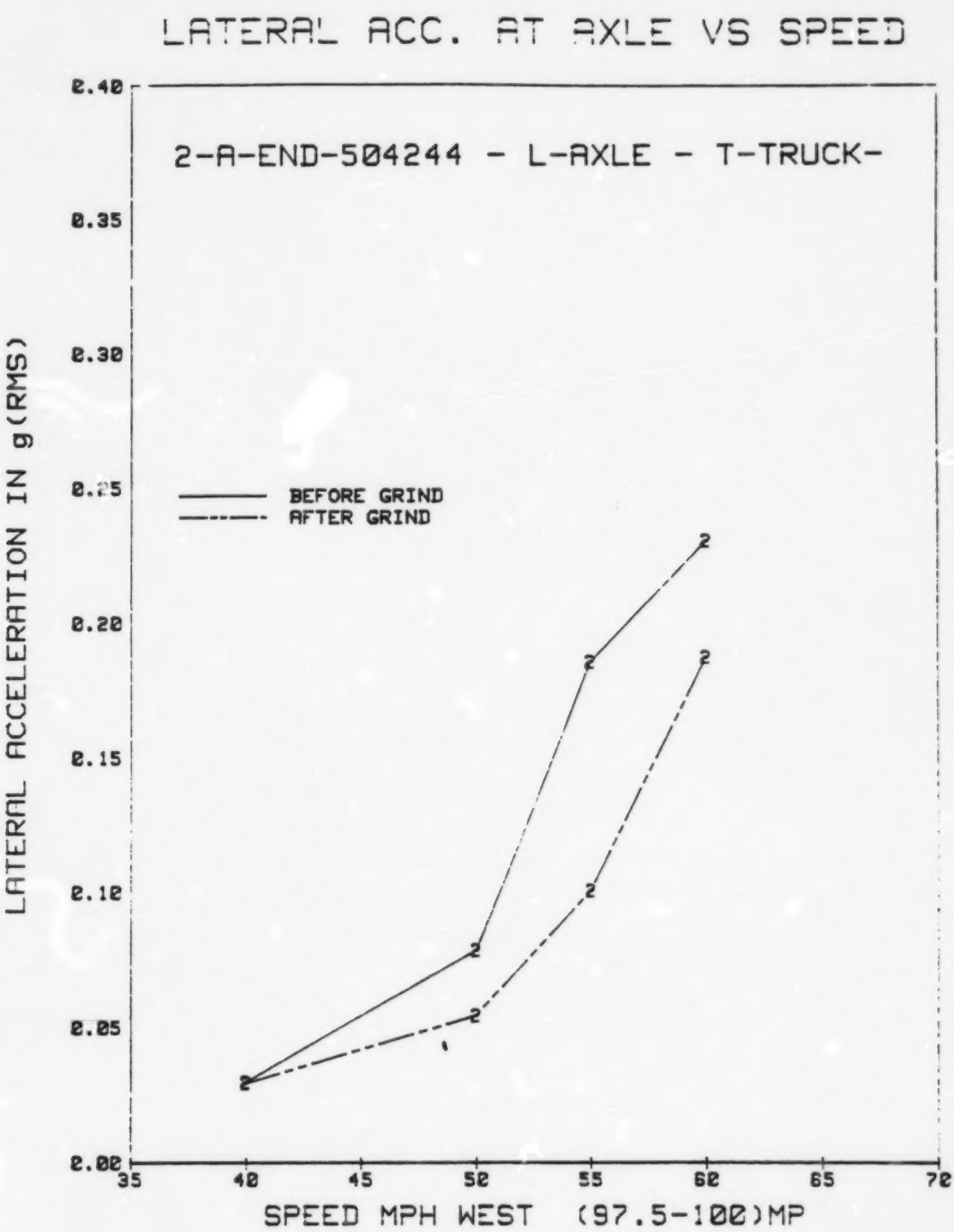
**Lateral Acceleration of CP 504244 -
B End vs Speed from Mile 96.5 to 97.5**

FIGURE A4



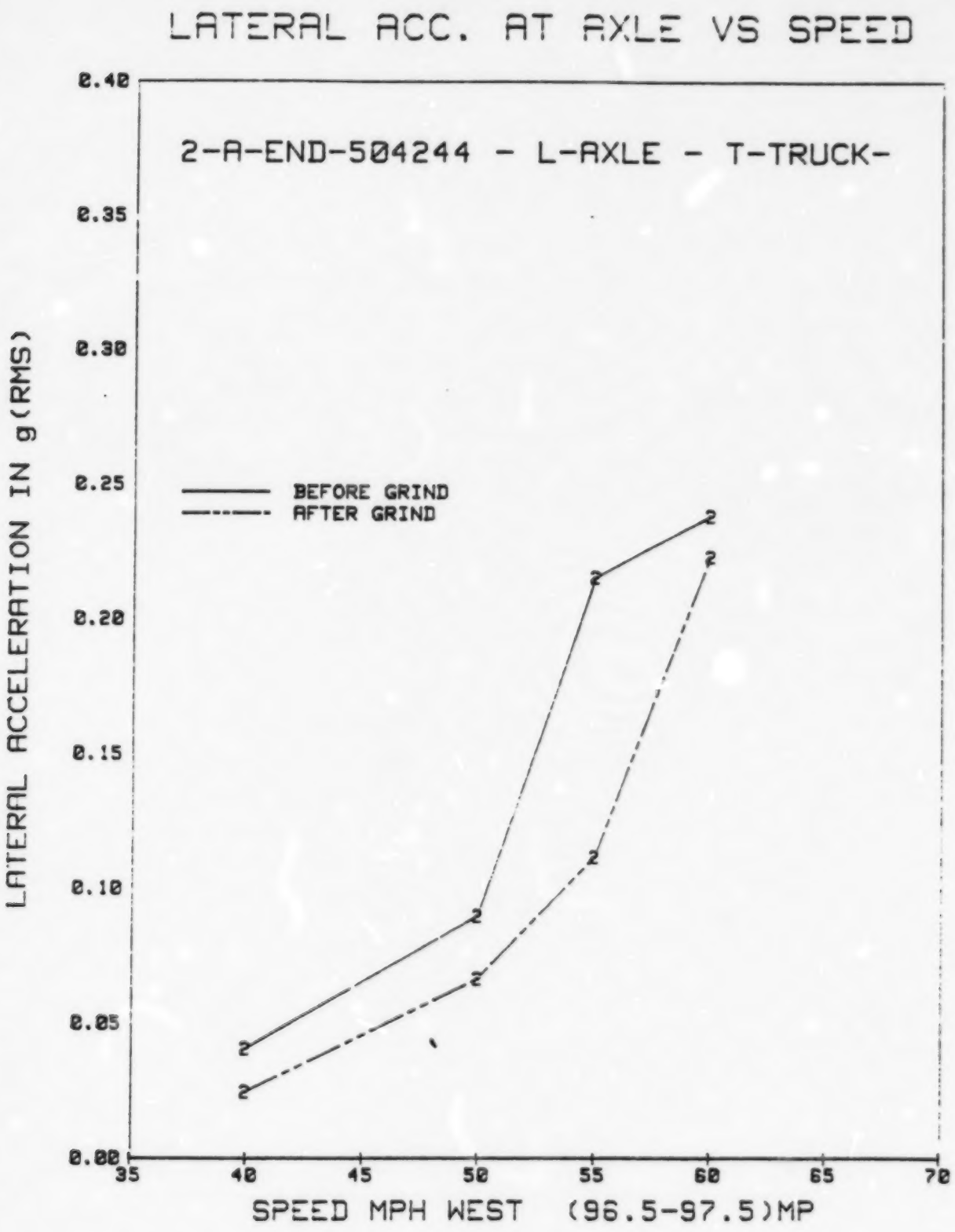
**Lateral Acceleration of CP 504244 -
A End vs Speed from Mile 90.9 to 96.5**

FIGURE A5



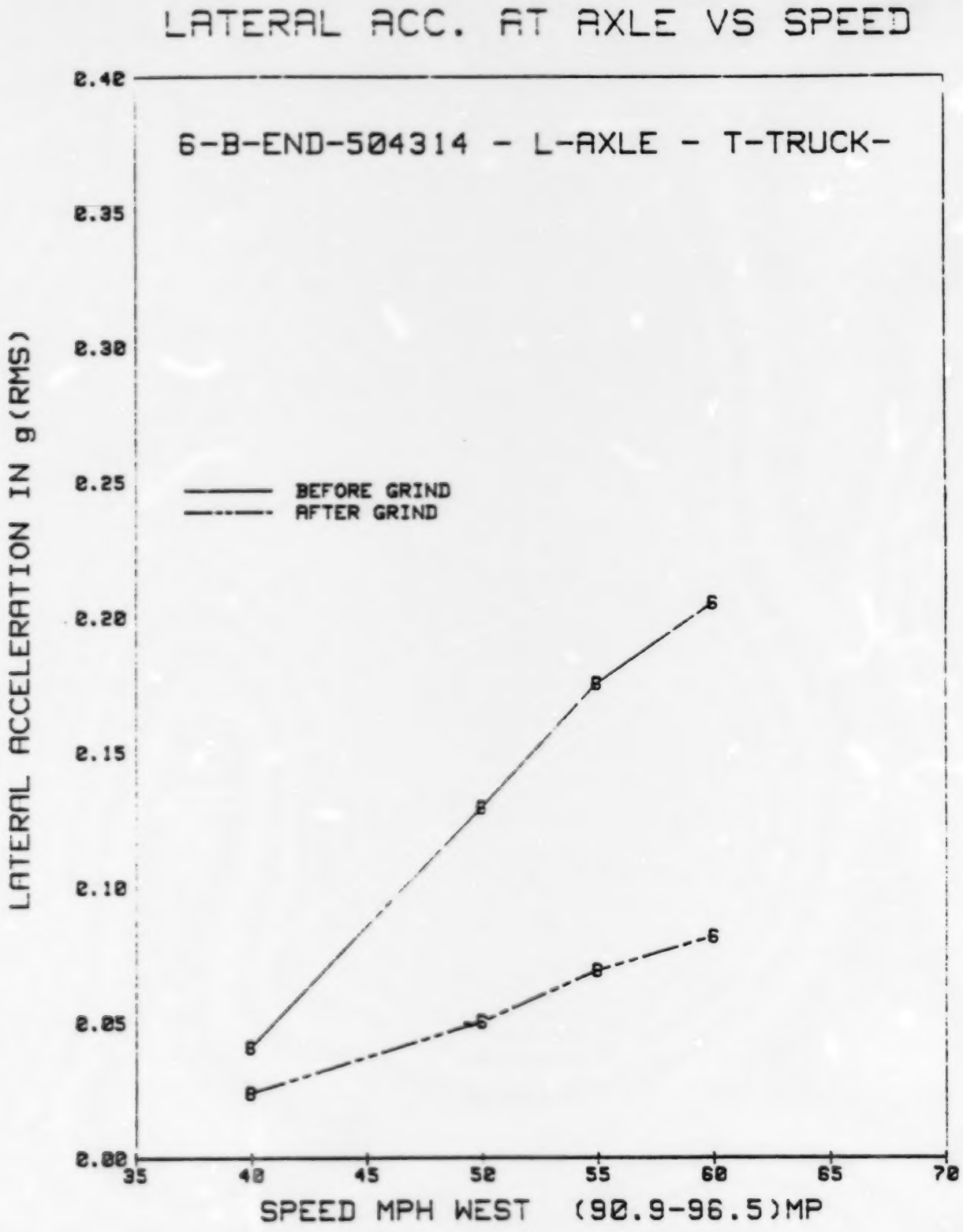
**Lateral Acceleration of CP 504244 -
A End vs Speed from Mile 97.5 to 100.0**

FIGURE A6



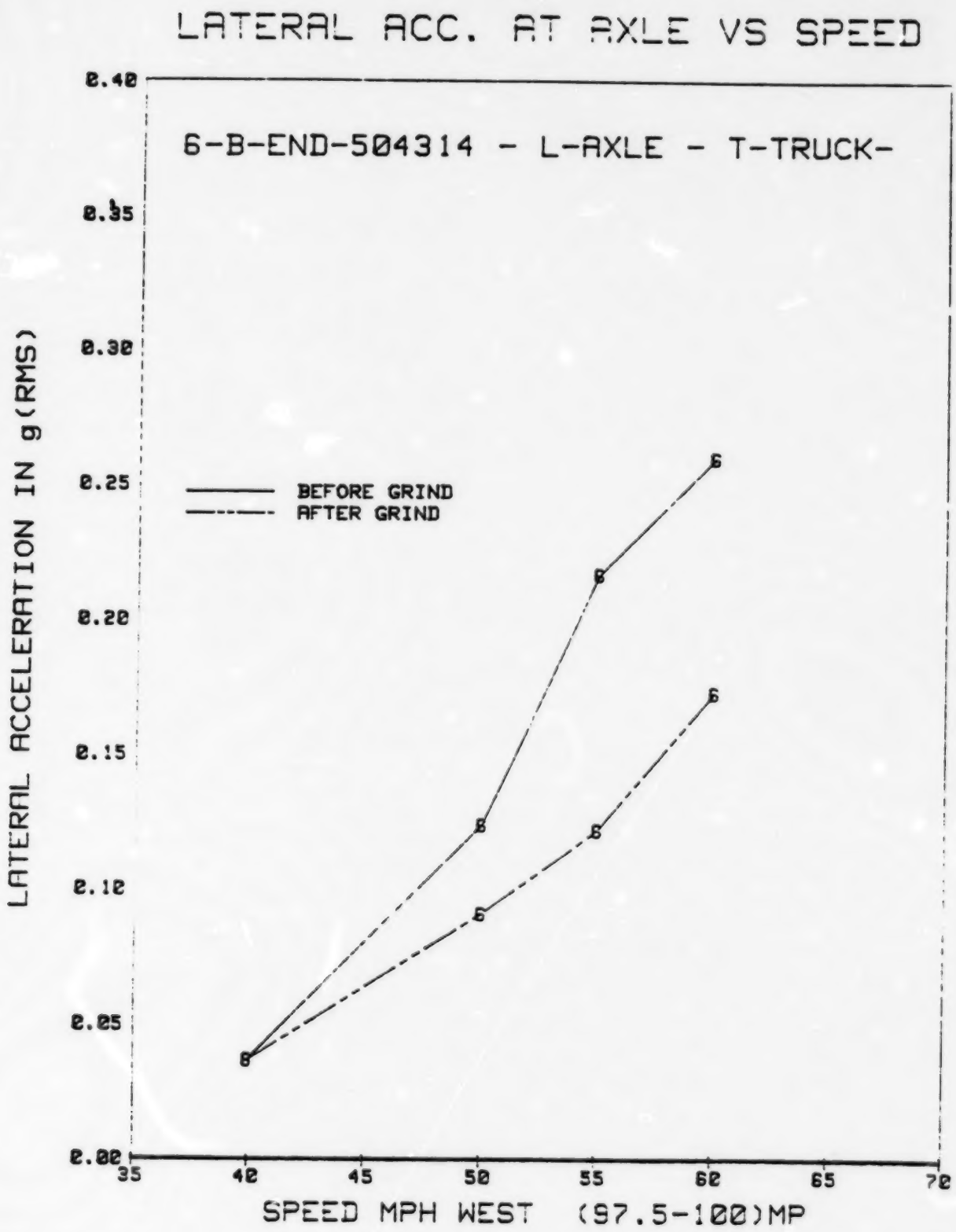
**Lateral Acceleration of CP 504244 -
A End vs Speed from Mile 96.5 to 97.5**

FIGURE A7



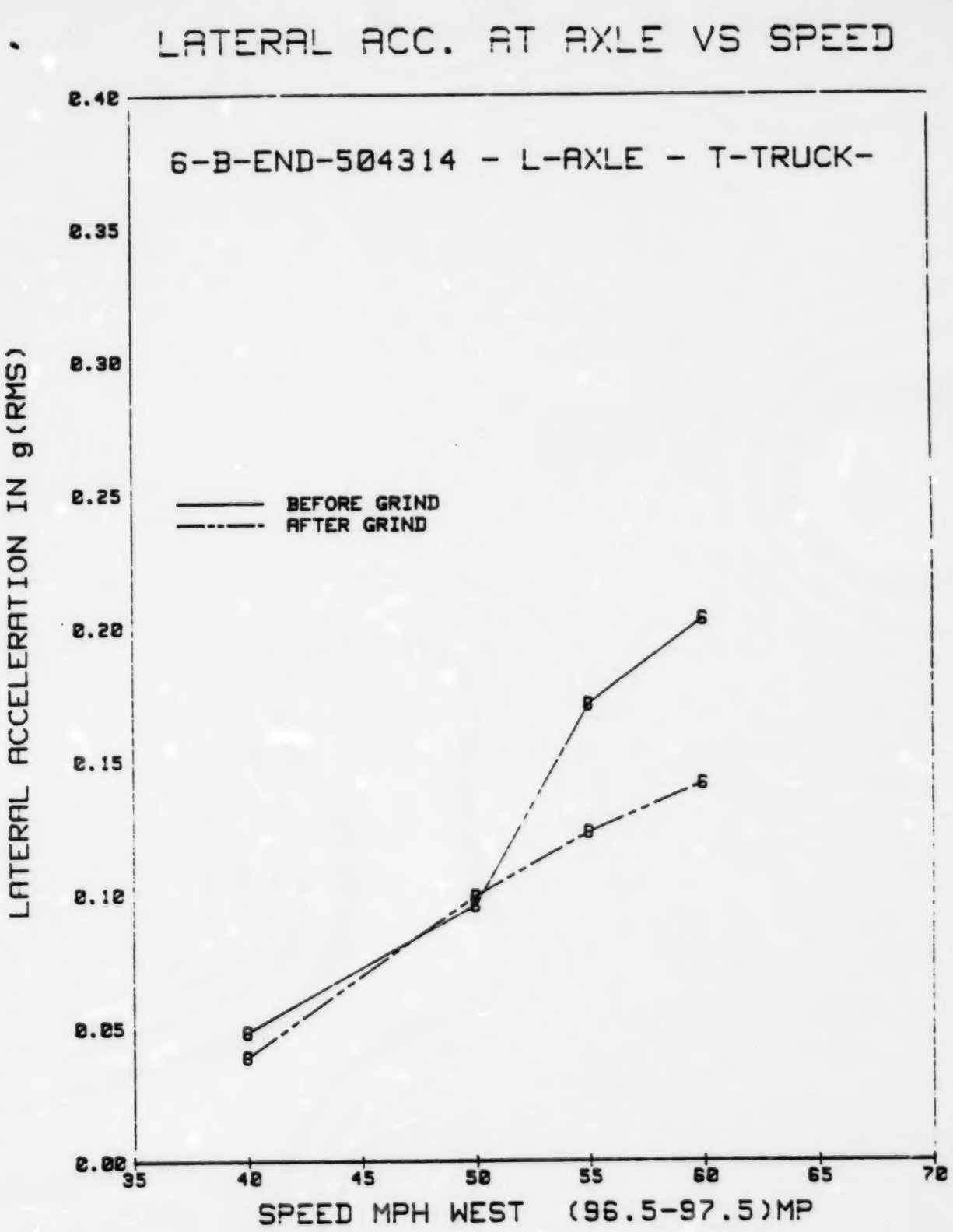
Lateral Acceleration of CP 504314 - B End vs Speed from Mile 90.9 to 96.5

FIGURE A8



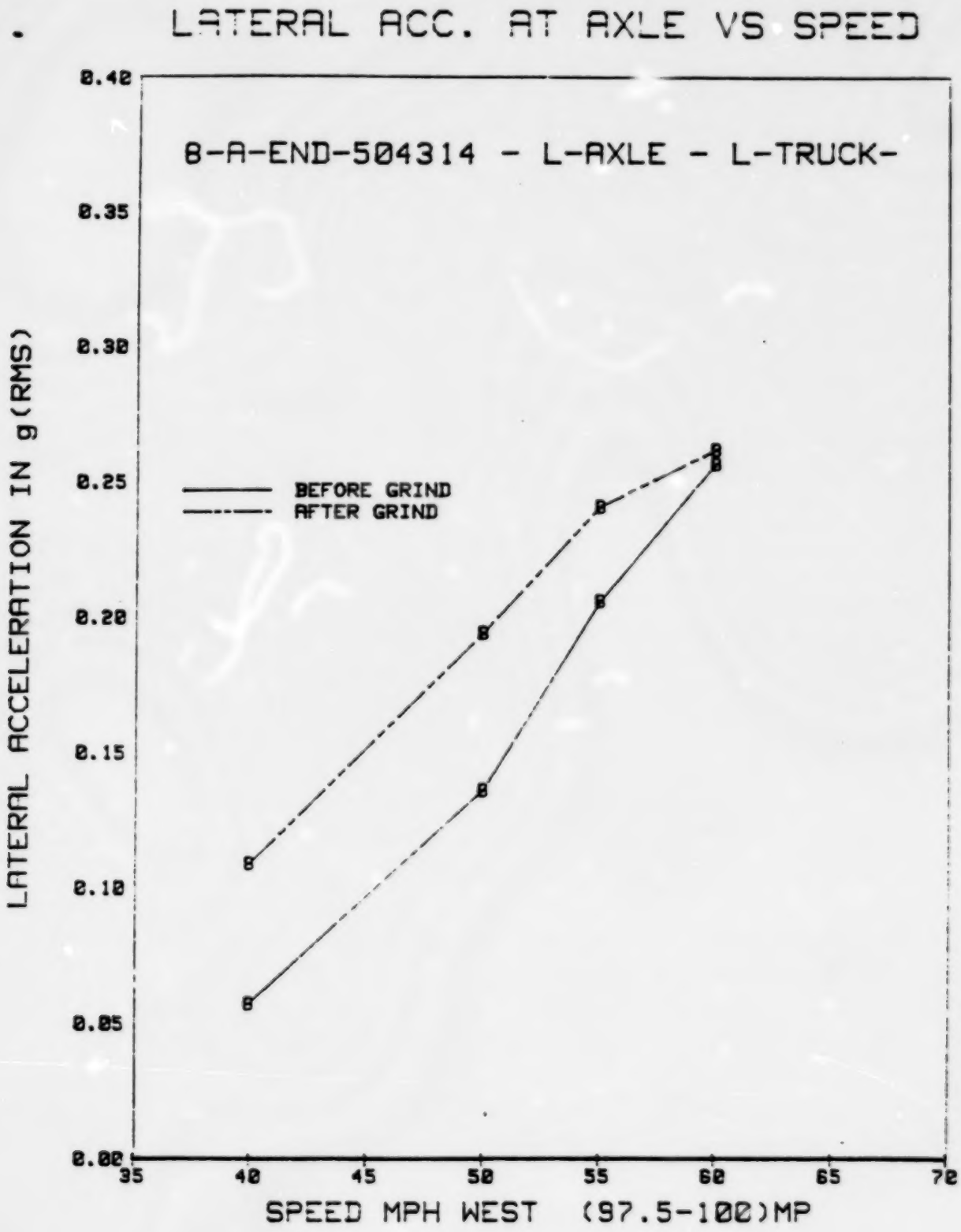
Lateral Acceleration of CP 504314 - B End vs Speed from Mile 97.5 to 100.0

FIGURE A9



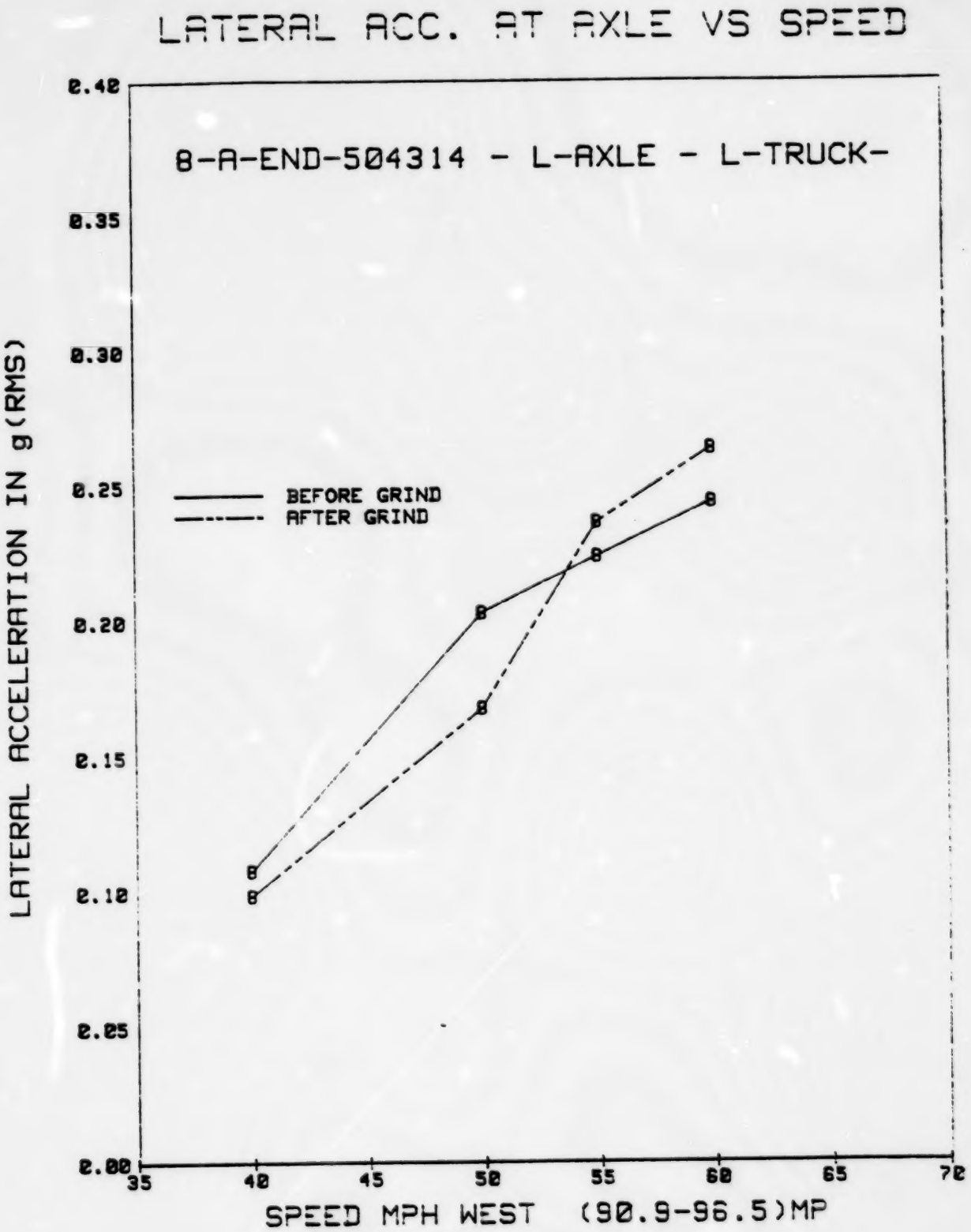
Lateral Acceleration of CP 504314 - B End vs Speed from Mile 96.5 to 97.5

FIGURE A10



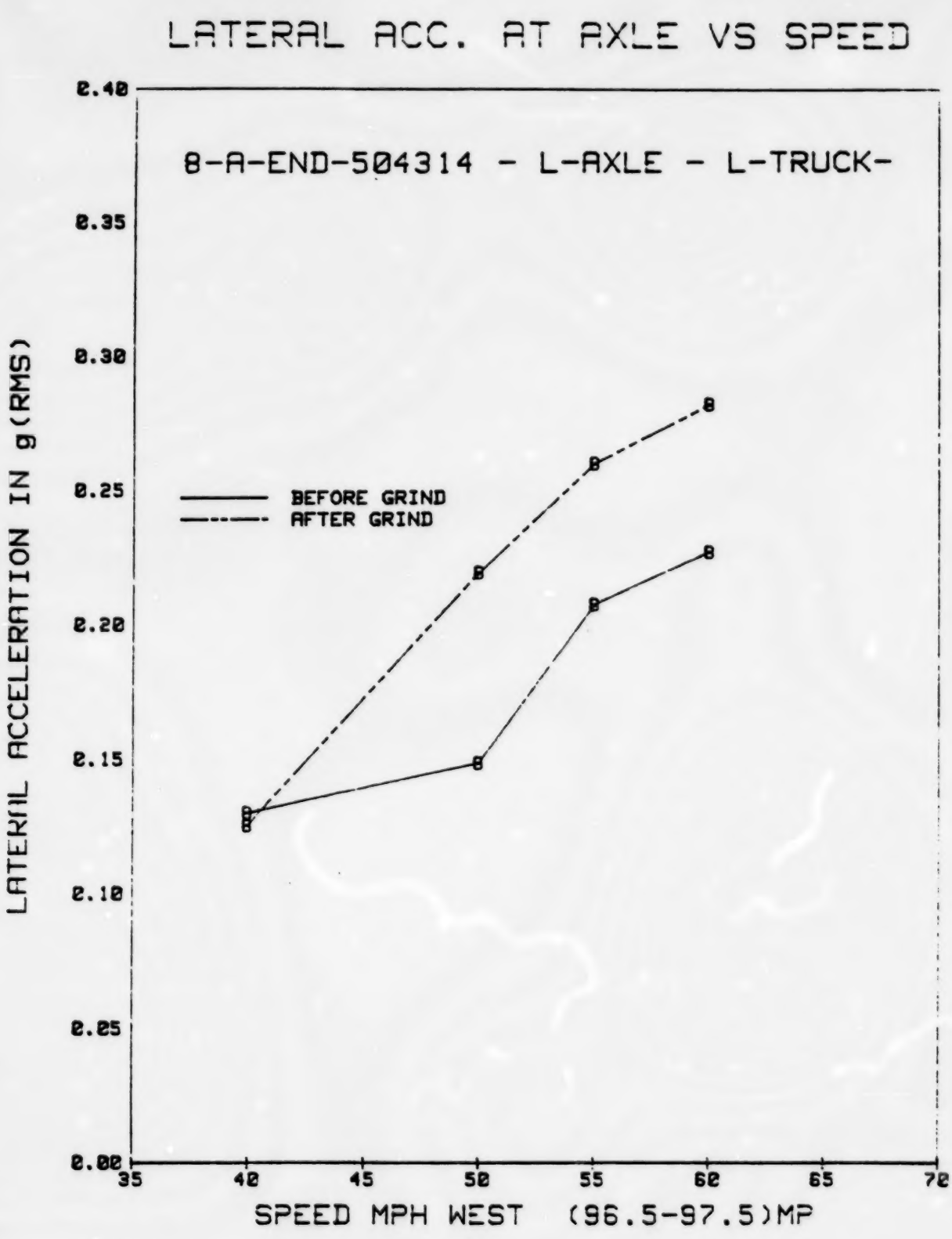
**Lateral Acceleration of CP 504314 -
A End vs Speed from Mile 90.9 to 96.5**

FIGURE A11



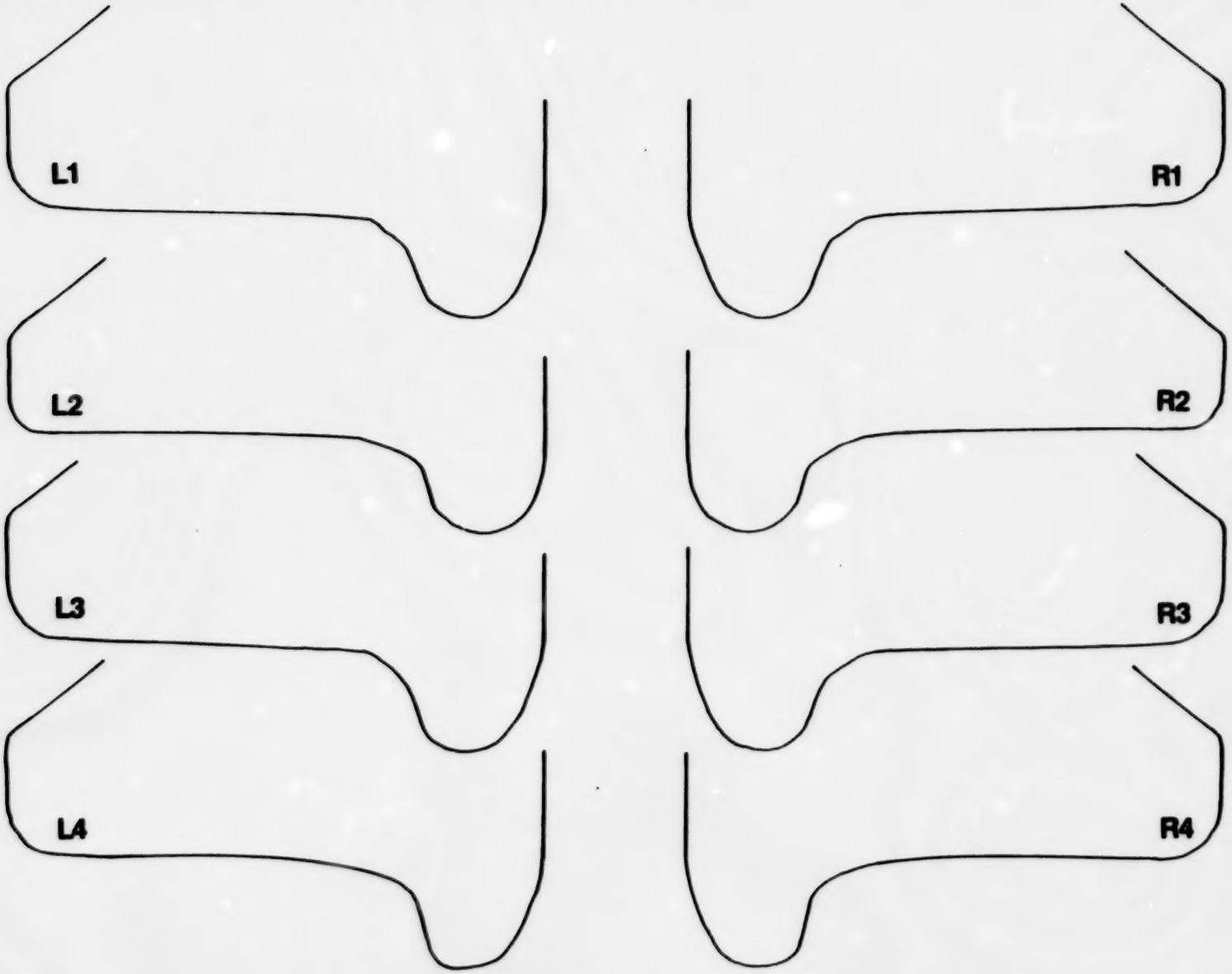
**Lateral Acceleration of CP 504314 -
A End vs Speed from Mile 97.5 to 100.0**

FIGURE A12



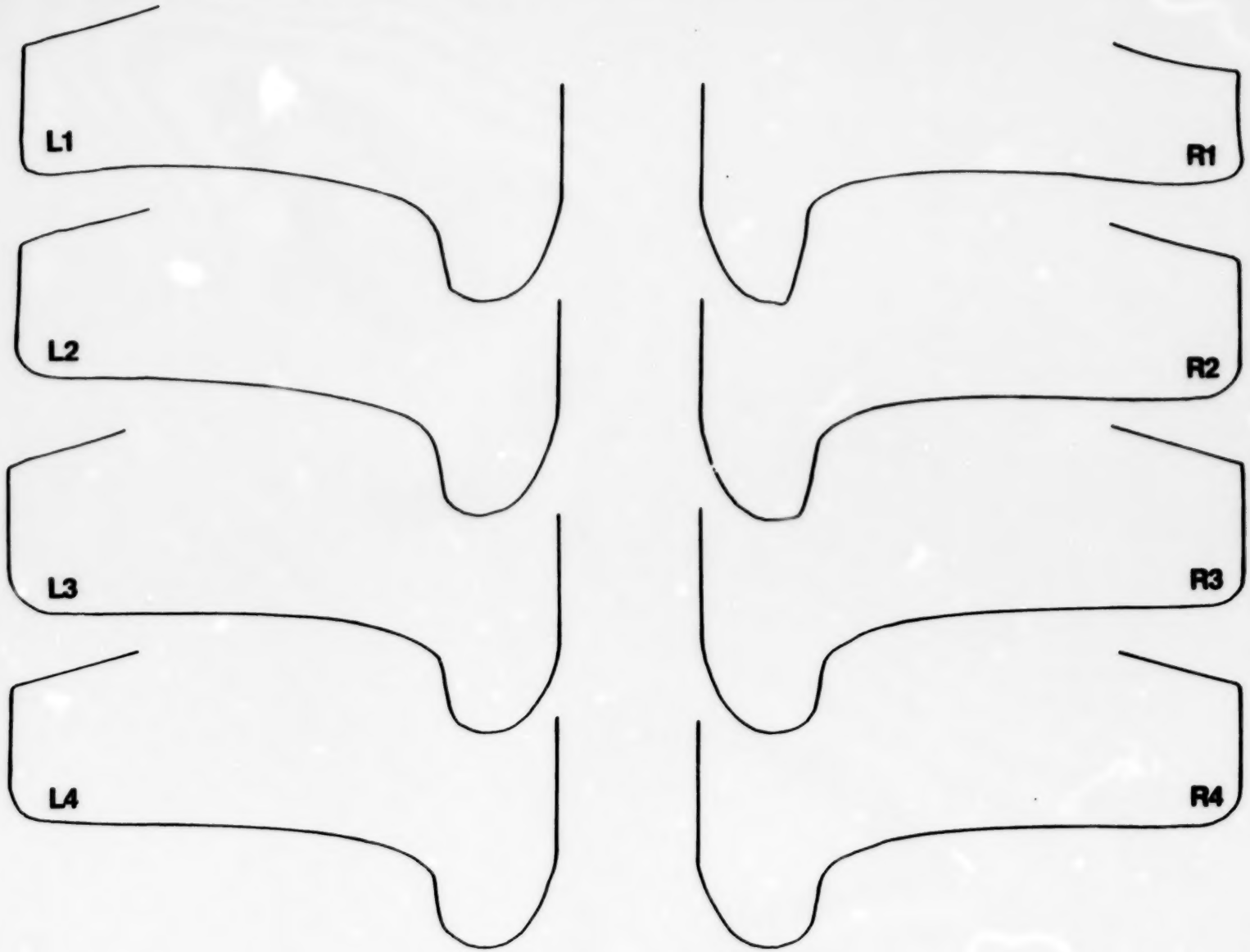
**Lateral Acceleration of CP 504314 -
A End vs Speed from Mile 96.5 to 97.5**

FIGURE A13



SERVICE WORN WHEEL PROFILES OF CAR CP 504244

FIGURE A14



SERVICE WORN WHEEL PROFILES OF CAR CP 504314

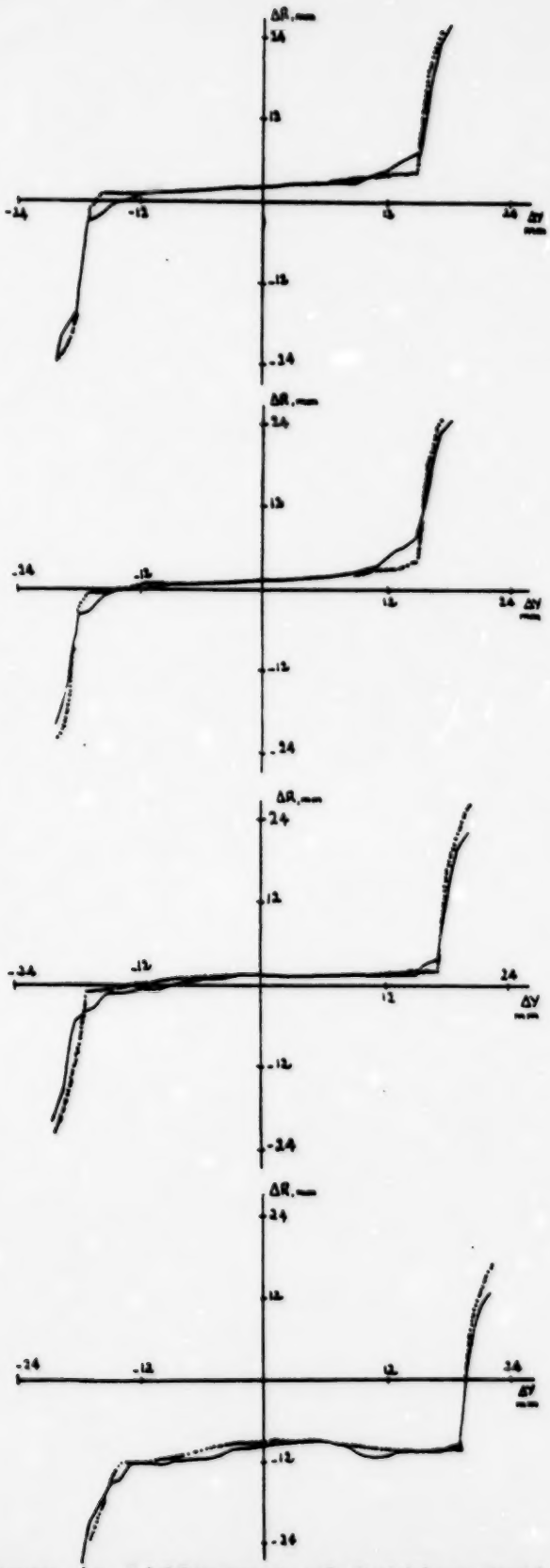
FIGURE A15

Right Wheel/Rail Contact of Axle 1
Car CP 504244 at MP 94.0

FIGURE A16

Left Wheel/Rail Contact of Axle 1
Car CP 504244 at MP 94.0

FIGURE A17

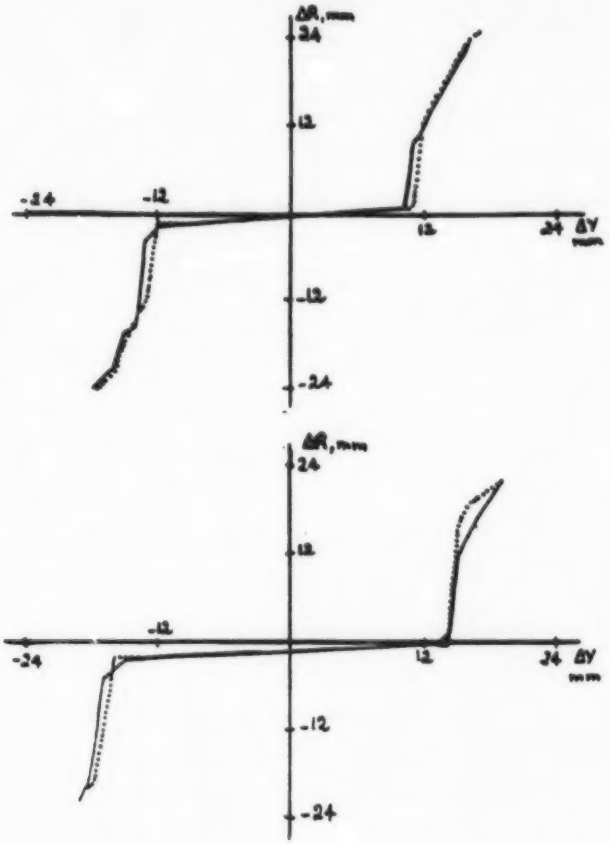


_____ Before Grinding

..... After Grinding

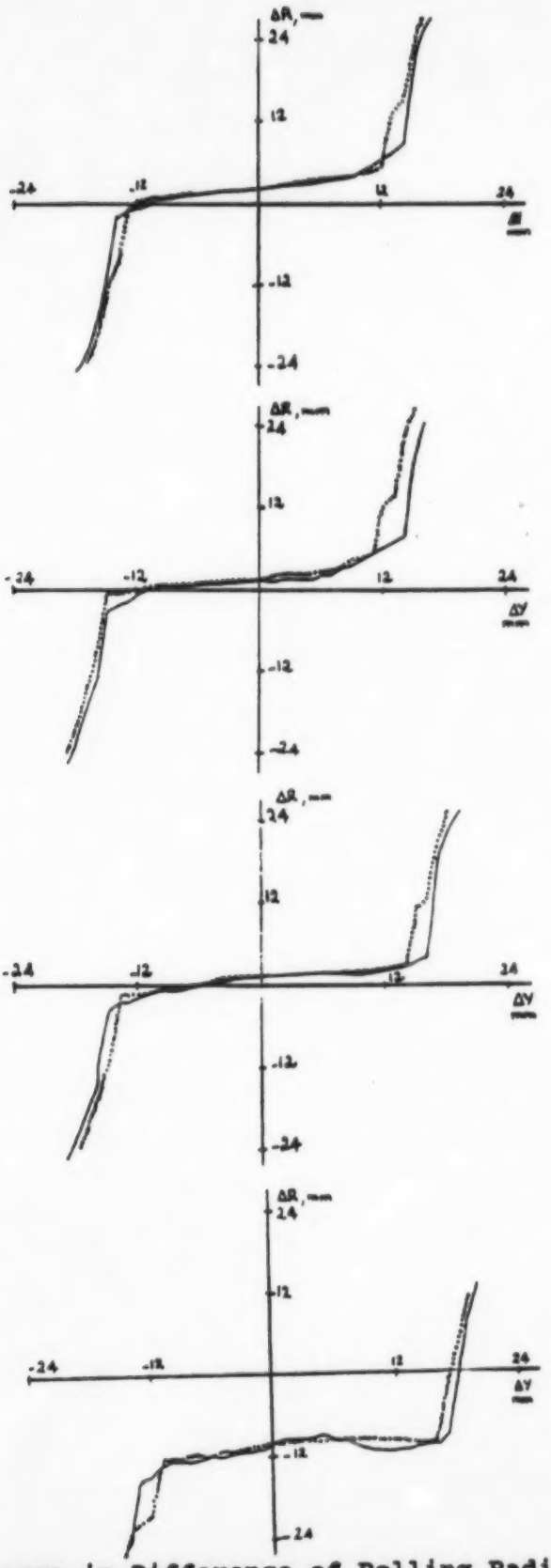
Change in Difference of Rolling Radii with Grinding for Car CP 504314 - Mileage 94.0

FIGURE A18



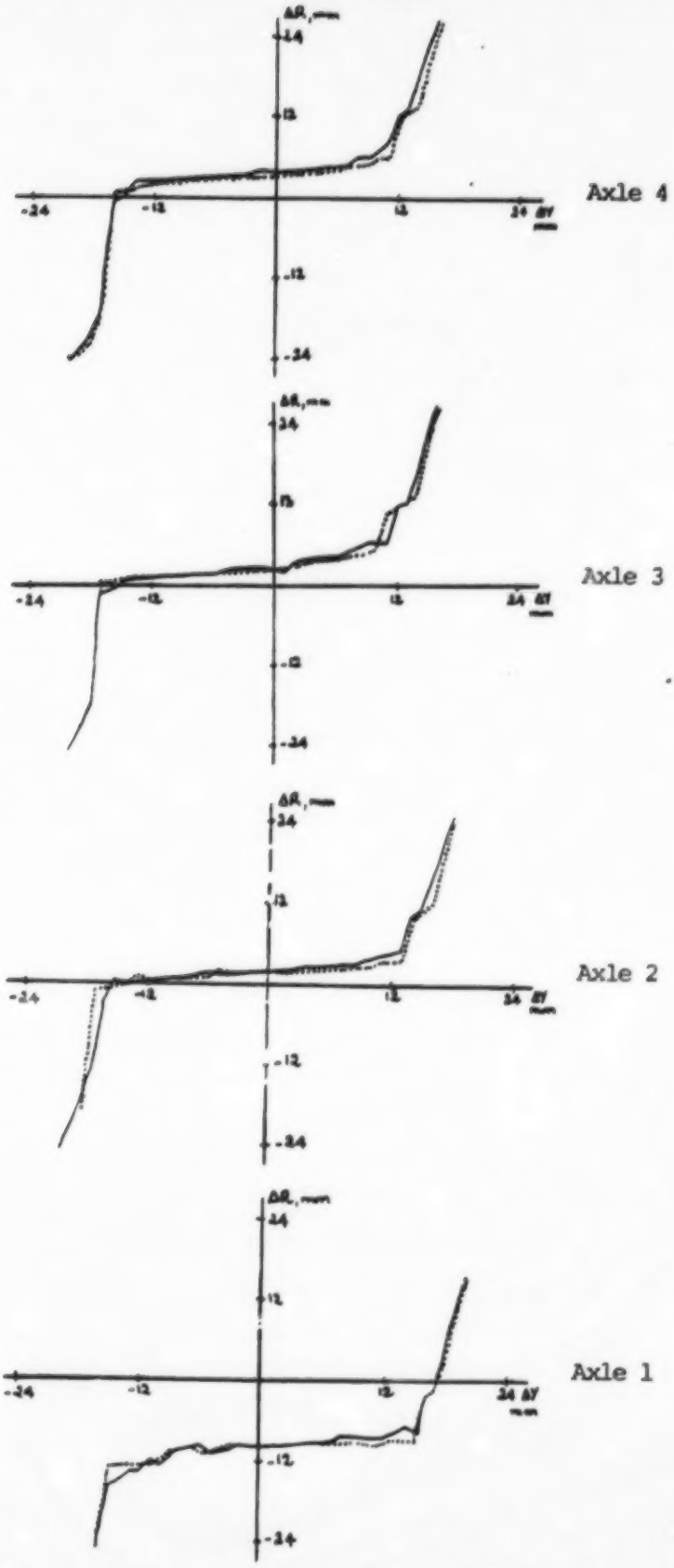
Change in Difference of Rolling Radii with Grinding for Car CP 504244 - Mileage 94.0

FIGURE A19



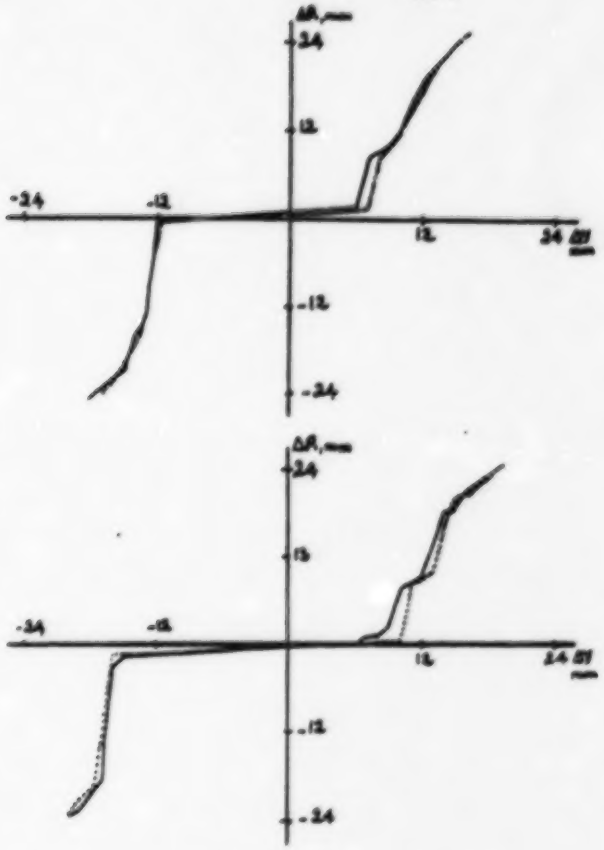
Change in Difference of Rolling Radi with Grinding for Car CP 504314 - Mileage 97.0

FIGURE A20



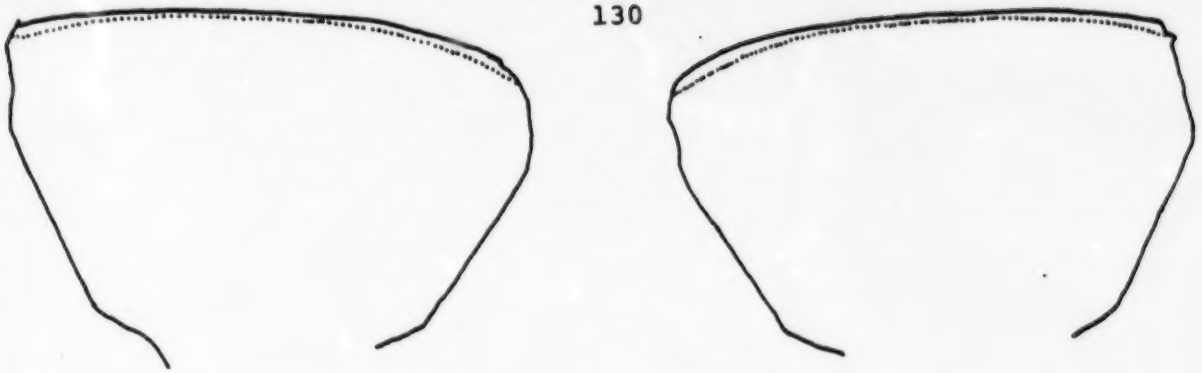
Change in Difference of Rolling Radii with Grinding for Car CP 504314 - Mileage 99.0

FIGURE A21

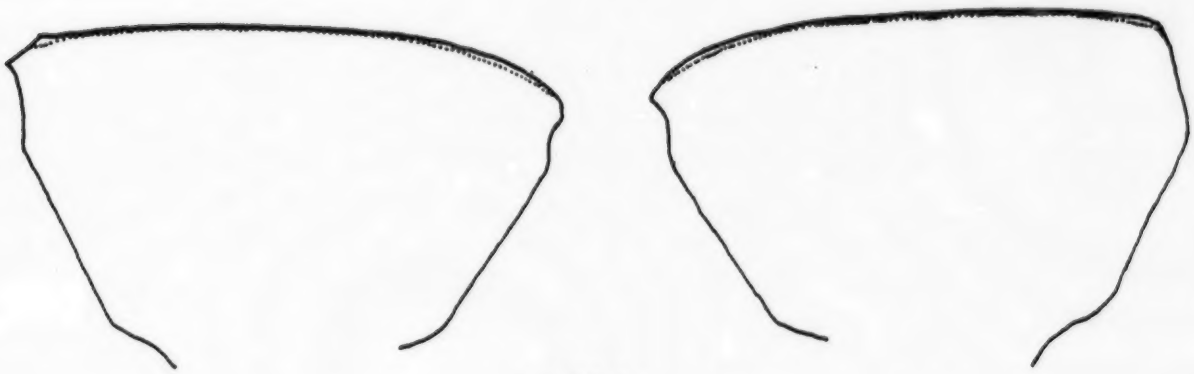


Change in Difference of Rolling Radii with Grinding for Car CP 504244 - Mileage 99.0

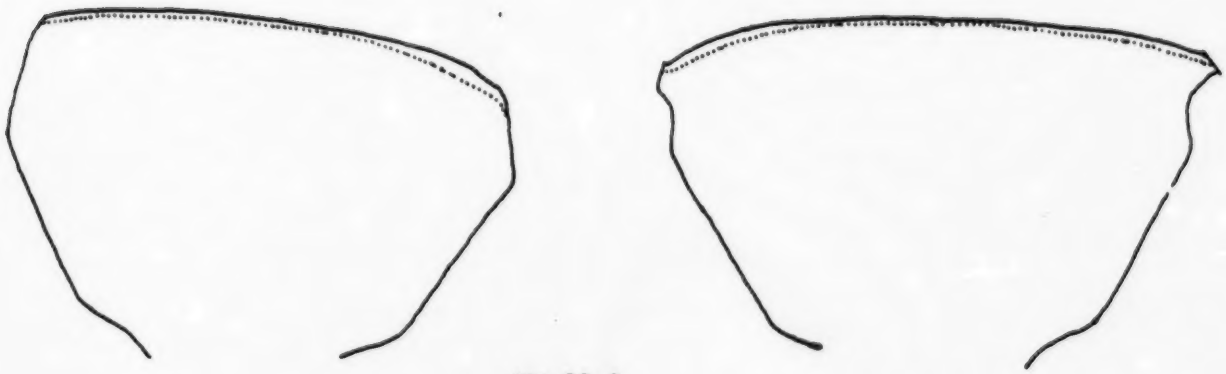
FIGURE A22



MP 94.0
(2 Passes)



MP 97.0
(1 Pass)



MP 99.0
(2 Passes)

____ Before Grinding

..... After Grinding

Before and After Grinding Profiles at
Mileages 94.0, 97.0 and 99.0

FIGURE A23